PROGRESSIVE PROBLEMS

IN

PHYSICS

BY

FRED R. MILLER

BOSTON ENGLISH HIGH SCHOOL

BOSTON, MASS.
D. C. HEATH & CO., PUBLISHERS
1908

PREFACE

In making a problem book as in writing a text-book it is necessary to have clearly in mind a method of presentation for each topic. In successive problems one point after another should be brought out slowly, clearly, and in a logical order. This *progressive* idea is the main feature of this book.

The problems are *numerous*, giving to both elementary and college preparatory classes ample material for drill, for review, and for the assignment of different home lessons to divisions doing the same work.

As the aim of the physics teacher is to teach physics, not mathematics, special effort has been made to *cut out all needless mathematical work* so as to reduce the amount of time required for mere numerical computation. If the teacher is thus able to assign, say, eight problems instead of five for a home lesson, his class will learn more physics with the same effort and enjoy it better.

As far as possible the problems have been made *practical* by using data from reliable scientific and commercial sources, so that the observant pupil may incidentally learn many interesting facts.

Attention is called to the use of the electrical units, *Circular Mil* and *Mil-Foot*, in many of the problems on Resistance. These units, long in general use by practical electricians and in technical schools, are extremely simple and are rapidly coming into use in elementary physics courses.

Thanks are due to Mr. N. Henry Black of the Roxbury Latin School, who gave generous assistance during the preparation and publication of the manuscript, to Mr. George A. Cowen of the West Roxbury High School, and to Mr. William F. Rice of the Boston Latin School. Most of the diagrams in this book were drawn by Theodore R. Kendall, a student in the Boston English High School.

F. R. M.

August 1, 1908.

CONTENTS

PROGRESSIVE PROBLEMS IN PHYSICS

PRELIMINARY

METRIC SYSTEM

1. Change 5 m. to centimeters; to millimeters; to kilometers.

2. Reduce 3 m. to centimeters; to kilometers; to millimeters.

3. Change 8520 m. to kilometers; to centimeters; to millimeters.

4. Change 5231.3 m. to kilometers; to centimeters; to millimeters.

5. A certain distance is equal to 73.2 cm. Change the decimal point so that the number shall give the distance in meters.

6. Given 75.3 Dm. Change the decimal point so that the distance shall be given in decimeters.

7. What is the difference in centimeters between 3 m. and 9 mm.?

8. What is the difference in centimeters between 5 m. and 25 mm.?

9. What part of a kilometer is 1 cm.?

10. What part of a meter is 1 mm.?

11. Change 2325 m. to centimeters; 8.25 km. to meters; 0.83 m. to millimeters.

12. Change 8325 cm. to meters; 7.32 km. to centimeters; 32.7 mm. to meters.

13. Reduce 2 km. + 14 m. to millimeters.

14. Reduce 3 km. + 5 m. + 3 cm. to centimeters.

15. Add 7 m., 3 cm., 9 mm., 5 km., and reduce the result to millimeters.

16. Add 80 mm., 3 cm., 2 km., 53 m., and reduce the result to centimeters.

17. Find the combined length of four boards which measure separately 7.45 m., 45.5 cm., 535 mm., and 3.8 m.

18. What is the total length of four strips of carpet which measure separately 2.35 m., 375 cm., 280 cm., and 1.375 m.?

19. Complete the table of square measure begun on page 215 of the Appendix.

20. When you reduce square meters to square centimeters, by what number do you multiply or divide?

21. How many square centimeters are there in a square meter?

22. How many square meters are there in a square kilometer?

23. Reduce 1 $m.^2$ to square millimeters.

24. How many square centimeters are there in a square kilometer?

25. Change 7 $km.^2$ to square meters.

26. Change 8.25 $cm.^2$ to square meters.

27. Change 35 $m.^2$ 4 $cm.^2$ to square centimeters.

28. How many square meters of carpet will cover a floor which is 10.5 m. long and 8 m. wide?

29. How many square meters in a rectangular surface 35.6 m. long and 22.4 m. wide?

30. How many square meters in a rectangular garden 3.2 Dm. long and 85.3 dm. wide?

31. Complete the table of cubic measure begun on page 215 of the Appendix.

32. When you reduce cubic centimeters to cubic meters, by what number do you multiply or divide?

33. How many cubic centimeters are there in a cubic meter?

34. In 8.71 $m.^3$ how many cubic centimeters?

35. Change 7 $dm.^3$ to cubic millimeters.

36. How many cubic meters in 5000 $dm.^3$? in 60,000 cc.?

37. A cellar 20 m. × 50 m. × 3 m. is to be excavated. What will it cost at 12 cents per cubic meter?

38. How many cubic centimeters are there in a block 12 cm. long, 8 cm. wide, and 5 cm. high?

39. How many cubic meters are there in a wall 25 m. long, 8.4 m. high, and 76 cm. wide?

40. A wood pile contains 1800 $m.^3$ It is 15 m. long and 12 m. wide. How high is it?

41. How many square centimeters are there in one face of a cube containing 729 cc.?

42. Complete the table of liquid and dry measure begun on page 215 of the Appendix.

43. What is a liter?

44. How many cubic decimeters are there in 1 l.? How many cubic centimeters?

45. How many liters are there in a cubic meter?

46. How many cubic centimeters are there in 1 l.? in 1 cl.? in 1 hl.?

47. Reduce 5 $m.^3$ to liters; to dekaliters; to deciliters.

48. How many cubic meters are there in 4 hl.?

49. How many liters are there in 110 $m.^3$? 110 $dm.^3$? 110 cc.?

50. Reduce 17.32 l. to cubic centimeters.

51. How many liters of capacity has a tank containing 2.5 $m.^3$?

52. At \$1.50 per hektoliter what is the cost of enough wheat to fill a bin 12 m. $\times$ $5\frac{1}{2}$ m. $\times$ 4 m.?

53. Complete the table of weight begun on page 215 of the Appendix.

54. Change 39.7 kg. to grams; to centigrams.

55. How many centigrams are there in 5 kg.? How many grams in 15,000 mg.?

56. Reduce 792.3 cg. to milligrams; to grams; to kilograms.

57. Change 5 kg. 5 cg. to grams; 2 kg. 3 g. to centigrams.

58. How many grams are there in 10 dg. + 1 cg. + 3 mg.?

59. Add 30 kg., 2 g., 30 cg., 3 mg., and express the result in grams.

60. Add 7 kg., 85 cg., 5 g., 30 cg., 700 mg., and express the result in centigrams.

61. What is the weight in grams of 25 cc. of water? What is the weight in kilograms of 30 l. of water?

62. If mercury weighs 13.6 times as much as water, what is the weight of 75 cc. of mercury? of 2 l. of mercury?

63. A tank is 10 by 9 by 5 cm. How many grams of water can it hold? How many kilograms of mercury?

64. A tank is 8.2 m. by 2.3 m. by 2.5 m. How many kilograms of water will it hold? how much mercury?

65. The dimensions of a meal chest are 3.2 m., .75 m., and 87.2 cm. How many liters of meal will it hold? How many kiloliters?

66. A rectangular watering trough is 180 cm. long, .43 m. wide, and 500 mm. deep. It is brimful of water. Express its contents in liters, cubic meters, grams, cubic decimeters, cubic centimeters, kilograms.

67. Find the length of a foot rule in centimeters.

68. A table top measures 2.4 m. by 80 cm. Find its length and width in inches.

69. A cubic foot of water weighs about 62.5 lb. Find its weight in kilograms.

70. How heavy in pounds is a package that weighs 35 kg.?

71. How many ounces would a 75-g. letter weigh?

72. A boy 5 ft. 2 in. tall and weighing 90 lb. can walk 3.8 mi. in an hour. Express these facts in the most appropriate metric units.

73. A horse 1.6 m. tall and weighing 500 kg. can travel 30 km. in two hours. Express these facts in English units.

DIVISION

Divide to three significant figures:

74. 247170 by 642.
75. 208670 by 385.
76. 128896 by 424.
77. 292175 by 725.
78. 1664493 by 831.
79. 1638468 by 234.

80. 177.354 by 334.
81. 109.802 by 434.
82. 286.382 by 8423.
83. 198.075 by 7923.
84. 0.810944 by 253.42.
85. 0.691320 by 123.45.
86. 2.341512 by 0.0072.
87. 0.770952 by 0.0024.
88. 0.00435 by 0.000052.
89. 0.000287 by 0.000021.
90. 0.0000324 by 0.00023.
91. 0.0000213 by 0.00015.
92. 2 by 742.
93. 5 by 323.

Reduce to a decimal of three significant figures:

94. $\frac{1}{278}$.
95. $\frac{5}{252}$.
96. $\frac{2}{842}$.
97. $\frac{3}{888}$.
98. $\frac{8}{427}$.
99. $\frac{6}{246}$.

SQUARE ROOT

Find the square root to three significant figures:

100. 5476.
101. 54756.
102. 4489.
103. 44521.
104. 1545049.
105. 10510564.
106. 0.3844.
107. 0.6241.
108. 3.
109. 5.
110. 0.3.
111. 0.5.
112. 424.637.
113. 930.527.
114. 0.00000065.
115. 0.00000082.

AREAS AND VOLUMES

In the following examples find the missing values:

(r = radius, d = diameter, c = circumference, a = area, v = volume)

The Circle

116. $r = 2$	$d = ?$	$c = ?$	$a = ?$
117. $r = 3$	$d = ?$	$c = ?$	$a = ?$
118. $r = ?$	$d = 7$	$c = ?$	$a = ?$
119. $r = ?$	$d = 8$	$c = ?$	$a = ?$

120.	$r = ?$	$d = ?$	$c = 18$	$a = ?$
121.	$r = ?$	$d = ?$	$c = 45$	$a = ?$
122.	$r = ?$	$d = ?$	$c = ?$	$a = 100$
123.	$r = ?$	$d = ?$	$c = ?$	$a = 90$

The Sphere

124.	$d = 3$	$a = ?$	$v = ?$
125.	$d = 20$	$a = ?$	$v = ?$
126.	$d = ?$	$a = 200$	$v = ?$
127.	$d = ?$	$a = 540$	$v = ?$
128.	$d = ?$	$a = ?$	$v = 1000$
129.	$d = ?$	$a = ?$	$v = 1728$

The Cylinder

(h = height, a = base area, l = lateral area)

130.	$a = 6$	$c = ?$	$a = ?$	$h = 10$	$l = ?$	$v = ?$
131.	$d = 20$	$c = ?$	$a = ?$	$h = 50$	$l = ?$	$v = ?$
132.	$d = ?$	$c = ?$	$a = ?$	$h = 8$	$l = ?$	$v = 1000$
133.	$d = ?$	$c = ?$	$a = ?$	$h = 12$	$l = ?$	$v = 2000$
134.	$d = ?$	$c = 35$	$a = ?$	$h = ?$	$l = 1200$	$v = ?$

MECHANICS

PASCAL'S PRINCIPLE

135. A cork 1 sq. in. in cross section is forced with a pressure of 30 lb. into the neck of a cylindrical bottle filled with water. The bottom of the bottle is 6 in. in diameter inside. Find the pressure on the bottom, caused by the cork.

136. A closed rectangular tank is 20 cm. high and has a base 30 × 40 cm. Through a hole 1 cm. square in the top it is filled with water. If a plug is then driven into this hole with a pressure of 500 g., what additional pressure will be exerted upon (*a*) the bottom? (*b*) each side? (*c*) the top?

137. A cubical tank holds 1728 cu. in. of water. Through an opening 1 in. square in the top a plug is pushed with a force of 50 lb. (*a*) What additional pressure does this cause on the inside of the tank? (*b*) How would the result be changed if the opening were halfway down the side instead of in the top?

138. A barrel full of vinegar is lying on its side with the bung uppermost. The head of the barrel has an inside diameter of 20 in. The inner diameter of the bung is 2 in. The bung is driven in so that it exerts a pressure of 20 lbs. upon the liquid directly beneath it. What is the additional pressure upon the head?

139. The area of the safety valve of a steam boiler (Fig. 1) is 3 sq. in. What weight must be placed *directly on the valve, D*, to keep it from blowing off (*i.e.* lifting) until the pressure in the boiler is 50 lb. per square inch?

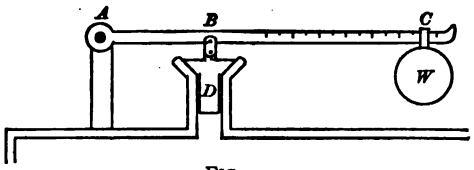

FIG. 1.

140. The diameter of the safety valve of a steam boiler is 1 in. and the weight *placed directly on it* is 20 lb. At what pressure will it blow?

141. The area of the safety valve of a steam boiler is 2 sq. in. and the weight upon it is 50 lb. When the steam within lifts the valve, what is the boiler pressure per square inch?

142. A pneumatic elevator (Fig. 2) is operated by compressed air supplied from a pump at a pressure of 90 lb. per square inch. If the area of the piston is 30 sq. in., how great can be the weight of the elevator car and its load?

143. An hydraulic elevator (Fig. 2) is run by water from the city mains. If the gauge shows the pressure to be 70 lb. per square inch, what load could be lifted by an elevator, the piston of which is 50 sq. in. in area?

144. A pneumatic lift (Fig. 2) is intended to carry a car and load weighing 3 T. The pressure gauge attached to the compressed air pump registers 70 lb. per square inch. What must be (*a*) the area of the piston? (*b*) the diameter of the piston?

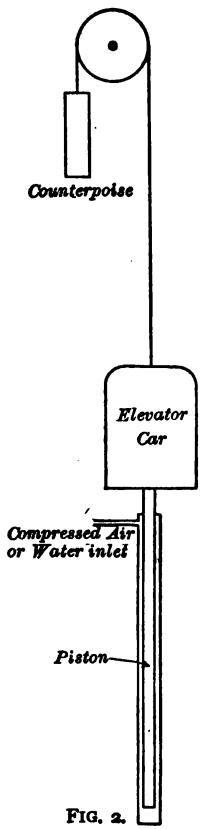

FIG. 2.

145. One piston of an hydraulic press (Fig. 3) is 5 cm.^{2} in area and the other is 100 cm.^{2} (*a*) What weight will be sustained on the large one by a pressure of 200 lb. on the small one? (*b*) What is the ratio of their areas? (*c*) What is the mechanical advantage?

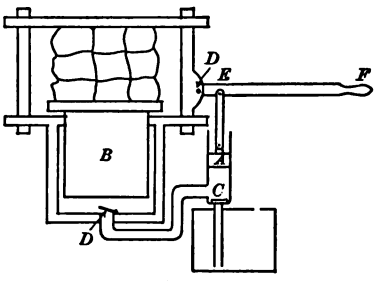

FIG. 3.

146. One piston of an hydraulic press (Fig. 3) is 3 sq. in. in area and the other is 50 sq. in. (*a*) What is the ratio of their areas? (*b*) What is the mechanical advantage? (*c*) What weight on the large piston can be held by a pressure of 100 lb. on the small one?

147. The large piston of an hydraulic press is 300 sq. in. in area; the small one is 5 sq. in. What pressure must be exerted on the small one to exert a pressure of 1 T. on the large one?

148. The areas of the pistons of an hydraulic press are 500 cm.^{2} and 10 cm.^{2} What force must be exerted on the small one to lift a weight of $\frac{1}{2}$ T.?

149. (*a*) In problem 148 when the small piston moves through a distance of 1 cm., how far will the large one move? (*b*) In order to move the large one 10 cm., how far must the small one move?

150. The diameters of the pistons in an hydraulic press are 20 in. and 2 in., and the pressure on the small piston is 50 lb. What pressure is exerted by the large piston?

151. The diameter of the plunger of an hydraulic press is 3 cm. and that of the ram is 24 cm. (*a*) What is the mechani-

cal advantage? (*b*) How great a pressure on the ram will be caused by a force of 40 kg. upon the plunger?

152. The ram of a pneumatic press is 200 sq. in. in area. What must be the area of the plunger to multiply the pressure by 80?

153. The ram of an hydraulic press is 30 in. in diameter. What must be the diameter of the plunger to multiply the pressure by 400?

DENSITY AND SPECIFIC GRAVITY

154. What is the weight of 200 cc. of copper, the density of which is 8.9 g. per cubic centimeter?

155. A window weight is made of 600 cc. of cast iron, the density of which is 7.2 g. per cubic centimeter. How heavy is this weight?

156. The density of gold is 19.3 g. per cubic centimeter. How heavy would be a gold brick 20 × 10 × 5 cm.?

157. What is the weight of a rectangular block of white pine 15 × 20 × 7 cm.? The density of white pine is 0.42 g. per cubic centimeter.

158. A piece of lead pipe weighs 800 g., and its density is 11.4 g. per cubic centimeter. How many cubic centimeters of lead are there in it?

159. The density of brass is 8.4 g. per cubic centimeter. Find the volume of a brass kilogram weight.

160. How many cubic centimeters in a block of maple wood weighing 3 kg.? The density of maple is 0.64 g. per cubic centimeter.

161. What is the capacity of a bottle that holds 4 kg. of alcohol, the density of which is 0.8 g. per cubic centimeter?

162. The density of brass is 525 lb. per cubic foot. How many cubic feet are there in 750 lb. of brass rod?

163. The weight of 500 cc. of silver is 5250 g. (*a*) What does 1 cc. of it weigh? (*b*) What is its density?

164. A rectangular block of wood measuring 20 × 35 × 8 cm. weighs 3920 g. (*a*) What is its density? (*b*) What does 1 cc. of it weigh?

165. A rectangular block of cast iron 12 × 8 × 5 cm. weighs 3456 g. (*a*) What is its density? (*b*) What would a cube of it 3 cm. on an edge weigh?

166. A sphere, the diameter of which is 53 mm., weighs 191.27 g. Find (*a*) its surface area; (*b*) its volume; (*c*) its density. If put into a beaker brimful of water, (*d*) what volume of water would run over? (*e*) what mass of water? (*f*) What volume of water would have the same mass as this sphere?

167. A cylinder has a diameter of 8 cm., a length of 12 cm., and a mass of 1570 g. Find (*a*) its lateral area; (*b*) its total surface area; (*c*) its volume; (*d*) its density. (*e*) If put into a tumbler brimful of water, what mass of water would overflow? (*f*) How many cubic centimeters of water would have the same mass as the cylinder?

168. A metal tube is 8 cm. long, has an outside diameter of 13 cm., an inside diameter of 5 cm., and weighs 8560 g. Find (*a*) the number of cubic centimeters of metal in it; (*b*) the density of the metal.

169. A graduate (Fig. 4) is filled with water to the 250 cc. mark. When a lump of sulphur weighing 90 g. is dropped in, the water rises to the 295 cc. mark. Find the density of sulphur.

170. The weight of a cubic foot of water is 62.5 lb. Find the weight of a cubic foot of each of the following substances: (*a*) aluminum, (*b*) marble, (*c*) gold, (*d*) sea water, (*e*) ice, (*f*) mercury. Their densities in grams and cubic centimeters are (*a*) 2.6, (*b*) 2.7, (*c*) 19.3, (*d*) 1.03, (*e*) 0.92, (*f*) 13.6.

171. How heavy is a cubic inch (*a*) of water, (*b*) of platinum? (Density of platinum is 21.3 g. per cubic centimeter.)

172. A brick 8 × 4 × 2 in. weighs 4.2 lb.; what is its density?

173. A cubic foot of lead weighs 710 lb. How many grams will a cubic centimeter weigh?

174. The dimensions of a rectangular hard pine block are 4.8, 7.6, and 5.1 cm. It weighs 113 g. or 4 oz. Find its density, (*a*) in the metric system; (*b*) in the English system. (There are 28,300 cc. in 1 cu. ft.)

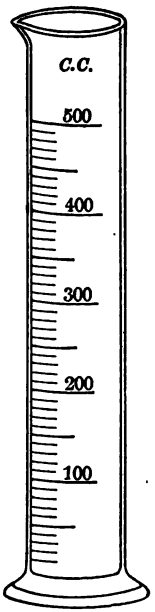

FIG. 4.

175. A rectangular hard pine block measures 7.8 × 4.9 × 5.1 cm. Its weight is 120 g. or 4.25 oz. Find the density in metric and English systems. (1 cu. ft. = 28,300 cc.)

176. A rectangular block of tin 30 × 10 × 5 cm. weighs 10,950 g. (*a*) What is its density? (*b*) What would an equal volume of water weigh? (*c*) What, then, is the specific gravity of tin? (*d*) What would a cubic foot of it weigh? (*e*) What is its density in the English system?

177. A rectangular block 8 × 10 × 16 cm. weighs 3 kg. What is (*a*) its density in C.G.S. units? (*b*) its specific gravity? (*c*) its density in English units? (*d*) What would 2 cu. ft. of it weigh?

178. A rectangular piece of timber $1 \times 1 \times 25$ ft. weighs 937.5 lb. (*a*) What is its density in English units? (*b*) What would an equal volume of water weigh? (*c*) What, then, is the specific gravity of the timber? (*d*) What is its density in metric units?

179. A rectangular body $18 \times 30 \times 48$ in. weighs 1500 lb. Find (*a*) its density in feet and pounds; (*b*) its specific gravity; (*c*) the weight of 5 cc.

180. The density of a certain body is 250 lb. per cubic foot. (*a*) What is its specific gravity? (*b*) What does a cubic centimeter of it weigh?

181. Two cubic feet of a certain substance weighs 600 lb. What is its density (*a*) in the English system? (*b*) in the metric system? What is its specific gravity (*c*) in the English system? (*d*) in the French system?

182. A body, the volume of which is 500 cc., has a density of 11 g. per cubic centimeter. (*a*) How much does it weigh? (*b*) What is its specific gravity?

183. A body, the volume of which is 500 cu. ft., has a density of 687.5 lb. per cubic foot. (*a*) What does it weigh? (*b*) What is its specific gravity?

184. The specific gravity of 1 cc. of mercury is 13.6. Find (*a*) the specific gravity of 3 cc.; (*b*) the weight of 3 cc.; (*c*) the specific gravity of 3 cu. ft.; (*d*) the weight of 3 cu. ft.; (*e*) the density in the C.G.S. system; (*f*) the density in the English system.

185. (*a*) How heavy is a piece of gold the size of an ordinary brick, $8 \times 4 \times 2$ in.? (*b*) How many cubic inches of gold could you carry easily?

186. A white pine plank 20 ft. long, 1 ft. wide, 2 in. thick will be how heavy?

187. The specific gravity of sulphuric acid is 1.84. A carboy holds 5 gal. of 231 cu. in. each. How heavy would the contents of this carboy be?

188. Your coal bin measures $6 \times 5 \times 10$ ft. The specific gravity of the coal in it is 1.5. How many tons of coal will it hold, assuming the coal to be packed solid?

189. Measure your coal bin in feet. Bring a piece of the coal to school and find its specific gravity. (*a*) Compute the number of tons it would hold if the coal were packed in solid. (*b*) How could you compute same for loose coal?

190. The ice box in your refrigerator measures $25 \times 15 \times 10$ in. The specific gravity of ice is 0.92. How many pounds of ice will it hold?

191. Measure the ice compartment of your refrigerator and compute the number of pounds it will hold. Specific gravity of ice = 0.92.

192. To find the weight in pounds of a cake of ice, take its measurements in inches and multiply the volume in cubic inches by —— a decimal. Find the decimal. Specific gravity of ice = 0.92.

193. A large bowlder is spherical in shape and has a diameter of 20 ft. A chip from it weighs 25 g. and raises the level of the water in a graduate (Fig. 4) 10 cc. How many tons does the bowlder weigh?

194. The average specific gravity of the earth is probably about 5.5. Its diameter is about 8000 miles. From these values find its mass in tons.

195. Find the volume (*a*) of an iron 50-g. weight; (*b*) of an iron 50-lb. weight.

196. If you buy 5 lb. of mercury, how many cubic inches should you get?

SPECIFIC GRAVITY: BOTTLE METHOD

197. A 150 cc. bottle holds 2050 g. of mercury. Find the specific gravity of mercury.

198. An empty bottle weighs 33 g. When full of water it weighs 103 g. and when full of brine it weighs 117 g. Find the specific gravity of brine.

199. An empty carboy weighs 20 lb. Full of water it weighs 100 lb., and full of sulphuric acid it weighs 140 lb. (*a*) What is the specific gravity of the acid? (*b*) Is it concentrated?

200. A certain bottle weighs 60 g. When full of alcohol it weighs 200 g. How much would it weigh if filled with water?

201. A specific gravity bottle weighs 50 g. when empty, 108.4 g. when full of ether, and 170 g. when full of chloroform. Find the specific gravity of chloroform.

202. It is found that a certain flask will contain 250 g. of water alone or 100 g. of water and 1260 g. of brass turnings. Find the specific gravity of brass.

203. A flask weighing 100 g. weighs 700 g. when just full of water. A paper of copper tacks weighing 180 g. is poured in, and after the overflowed water has run off, the flask weighs 860 g. Find the specific gravity of copper.

ARCHIMEDES' PRINCIPLE

204. A rectangular block $20 \times 5 \times 4$ cm. is placed in water with its upper 5×4 face parallel to the surface of the water and 10 cm. below it. Find (*a*) the downward pressure upon the top; (*b*) the upward pressure upon the bottom; (*c*) the buoyant force; (*d*) the weight of the displaced water. (*e*) State the principle demonstrated.

205. A cubical block of stone 6 cm. on an edge is lowered into water with its lower face horizontal and 16 cm. below the surface of the water. Find (*a*) the pressure upon top and bottom; (*b*) the difference between upward and downward pressures. If the block were lowered 40 cm. deeper, what would be (*c*) the pressure upon top and bottom? (*d*) the difference between upward and downward pressures?

206. A rectangular solid $8 \times 5 \times 4$ cm. is sunk in water with its upper 8×5 side horizontal and 12 cm. below the surface. (*a*) Find the difference between the upward and the downward pressures. (*b*) Find the volume of the displaced water. (*c*) State Archimedes' principle.

207. (*a*) What volume of water does a cubic decimeter of iron displace when immersed? (*b*) What weight of water? (*c*) What buoyant force does the water exert upon this iron? (*d*) What would it exert upon 2 dm.^{3} of iron? (*e*) Upon 2 dm.^{3} of lead?

208. (*a*) What volume of water does a cubic foot of iron displace when immersed in water? (*b*) What weight of water does it displace? (*c*) How much weight would this cubic foot of iron lose? (*d*) How much would a cubic foot of lead lose?

209. (*a*) Find the loss of weight of 50 cc. of granite when weighed in water. (*b*) If the granite weighs 125 g. in air, what will it weigh in water? (*c*) Find the loss of weight of 50 cu. ft. of granite when weighed in water. (*d*) If the granite weighs 7800 lb. in air, what will it weigh in water?

210. (*a*) What would be the weight of a rectangular block of tin having dimensions $6 \times 12 \times 12$ cm.? (*b*) What would it weigh in water? (*c*) What would be the weight of this block if its dimensions were $6 \times 12 \times 12$ in.? (*d*) What would it weigh in water?

211. (*a*) What is the volume of a lead kilogram weight? (*b*) What weight would it lose in water? (*c*) What is the volume of a lead half-ton weight? (*d*) How much less would it weigh in water?

212. (*a*) A body weighs 200 g. out of water and 50 g. in water. What is its volume? (*b*) If the body weighed 200 lb. out of water and 50 lb. in water, what would be its volume?

213. Eighty cubic centimeters of a given substance weighs 200 g. in water. (*a*) How much does it weigh in air? (*b*) What does the water it displaces weigh?

214. (*a*) What would 12 cc. of silver weigh in air? (*b*) What would it lose in water? (*c*) What would it weigh in alcohol?

215. A cube 5 cm. on an edge weighs 350 g. in water. (*a*) What does it weigh in air? (*b*) What does it weigh in kerosene?

216. A piece of marble loses 75 g. in water. What will it weigh in alcohol?

217. (*a*) How much would 50 cc. of cast iron lose in mercury? (*b*) What would it weigh in mercury? (*c*) Interpret your answer.

218. How much would a cubic foot of brass weigh in kerosene?

219. A metal casting weighs 3000 lb. In water it weighs 2500 lb. Find (*a*) its specific gravity; (*b*) its weight in sea water.

220. A piece of rock weighs 200 g. In alcohol it weighs 180 g. What does it weigh in sea water?

221. A granite rock used as an anchor becomes 20 lb. heavier as it is raised out of the water. What does the anchor weigh in air?

SPECIFIC GRAVITY OF SOLIDS HEAVIER THAN WATER

222. A body loses 50 g. when immersed in water. (*a*) What does an equal volume of water weigh? (*b*) If the body weighs 200 g. in air, how many times as heavy as water is it, bulk for bulk? (*c*) What is its specific gravity? (*d*) What is its density in the metric system? (*e*) in the English system?

223. A body loses 50 lb. when immersed in water. (*a*) What does an equal volume of water weigh? (*b*) If the body weighs 200 lb. in air, what is its specific gravity? (*c*) What is its density in the English system? (*d*) in the metric system?

224. A body weighs 900 g. in air and 600 g. in water. Find (*a*) its volume; (*b*) the weight of an equal volume of water; (*c*) the specific gravity of the body; (*d*) its density in the C.G.S. system; (*e*) its density in the English system.

225. A body weighs 900 lb. in air and 600 lb. in water. Find (*a*) the weight of an equal volume of water; (*b*) the specific gravity of the body; (*c*) its volume; (*d*) its density in pounds and cubic feet; (*e*) its density in grams and cubic centimeters.

226. A block of tin weighs 65.7 g. in air and 56.7 g. in water. Find (*a*) its volume; (*b*) its specific gravity.

227. A lump of zinc weighs 71 lb. in air and 61 lb. in water. Find (*a*) its volume, and (*b*) its specific gravity.

228. A glass bottle weighs 31.2 g. in air and 19.2 g. in water. Find (*a*) how many cubic centimeters of glass were used in making the bottle; (*b*) its specific gravity.

229. (*a*) What is the specific gravity of a substance that weighs x g. in air and y g. in water? (*b*) What is its volume?

230. (*a*) What is the specific gravity of a substance that weighs x lb. in air and y lb. in water? (*b*) What is its volume?

231. A ton of iron weighs only 1725 lb. in water. (*a*) How many cubic feet are there of it? (*b*) How heavy is 1 cu. ft.? (*c*) How heavy is 1 cc.?

232. (*a*) How much weight would 50 cc. of aluminum lose when immersed in water? (*b*) If it weighs 80 g. in water, what is its specific gravity?

233. Two hundred cubic centimeters of marble weighs 340 g. in water. Find its specific gravity.

234. A rectangular block of metal 20 × 10 × 5 cm. weighs 4 kg. in water. What is its specific gravity?

235. A rectangular block 5 × 2 × 1 ft. weighs ½ T. in water. What is its specific gravity?

236. A body the density of which is 6 g. per cubic centimeter loses 200 g. in water. Find (*a*) its volume; (*b*) its weight; (*c*) the weight of 2 cu. ft. of it.

237. A wrought-iron anchor loses 40 kg. in water. What is its weight?

SPECIFIC GRAVITY OF A LIQUID: SINKER METHOD

238. A stone weighs 50 g. in air, 30 g. in water, and 34 g. in alcohol. Find (*a*) the loss in water; (*b*) the loss in alcohol; (*c*) the volume of the stone; (*d*) the weight of this volume of water; (*e*) the weight of this volume of alcohol; (*f*) the specific gravity of alcohol; (*g*) the specific gravity of the stone.

239. A glass stopper loses 40 g. in water and 73 g. in sulphuric acid. Find the specific gravity of the acid.

240. A body loses 9 lb. in water and 7.1 lb. in kerosene. Find the specific gravity of kerosene.

241. A body weighs 200 g. in air, 120 g. in water, and 142 g. in ether. Find (*a*) the specific gravity of ether; (*b*) the volume of the displaced ether.

242. A block of tin weighs 100 lb. in air, 86.3 lb. in water, and 83.6 lb. in copper sulphate solution. Find (*a*) the specific gravity of the sulphate; (*b*) the volume of sulphate displaced.

243. A sinker weighs 300 g. in air, 250 g. in water, and loses 45 g. in another liquid. (*a*) Is the other liquid denser or lighter than water? What is the specific gravity (*b*) of the sinker? (*c*) of the other liquid?

244. A lump of sulphur weighs 150 g. in air, 75 g. in water, and 100 g. in gasolene. Find (*a*) the volume of the sulphur; (*b*) its specific gravity; (*c*) the weight of a cubic foot of gasolene.

245. A body weighs x g. in air, y g. in water, and z g. in another liquid. Find (*a*) the specific gravity of the body; (*b*) its volume; (*c*) the specific gravity of the other liquid.

246. A body weighs x lb. in air, y lb. in water, and z lb. in another liquid. Find (*a*) the specific gravity of the body; (*b*) its volume; (*c*) the specific gravity of the other liquid.

FLOATING BODIES

247. A live fish weighing 2 lb. is put into a tank brimful of water and weighing 50 lb. How much will the tank and all weigh now?

248. One of the modern battleships has a displacement of 21,000 T. (*i.e.* displaces 21,000 T. of water). (*a*) What does it weigh? (*b*) Would it sink deeper or rise higher in passing from a river to the ocean?

249. A skiff weighs 125 lb. How many cubic feet of water will this boat displace when it is carrying two persons weighing together 250 lb.?

250. A mud scow whose hull is rectangular, 60 ft. long by 40 ft. wide, draws 3 ft. of water (*i.e.* its bottom is 3 ft. below the surface of the water), when empty, in fresh water. When loaded with mud from a dredge, it draws 7 ft. of water. (*a*) What does the scow alone weigh? (*b*) What does its load weigh?

251. A rectangular lighter with vertical sides is 50 ft. long by 30 ft. wide. After it has been loaded with granite, it has sunk 2 ft. deeper in the water. How many tons of granite have been put aboard if the lighter floats (*a*) in fresh water? (*b*) in sea water?

252. How deep would the lighter in problem 251 have sunk in fresh water if 100 T. had been loaded upon it?

253. A rectangular rod $3 \times 3 \times 25$ cm. floats upright in water with all but 5 cm. of its length submerged. (*a*) How much does the stick weigh? (*b*) How many cubic centimeters of brass placed on top will just submerge the stick?

254. An empty kerosene barrel weighs 50 lb., is 30 in. long inside, and has an average internal diameter of 20 in. (*a*) When bunged tightly and placed in water, what weight will it support? Neglect the weight of the air contained in it. Such barrels are used under floats at boat landings, to give them greater buoyancy. (*b*) Would the barrels be more effective if filled with compressed air? Why?

255. A cube of cork 10 cm. on an edge weighs 250 g. (*a*) How many grams of water will it displace when floating? (*b*) How far will it sink? (*c*) What fraction of its entire volume will be submerged? (*d*) What is its specific gravity? (*e*) Make a statement to show the relation between answers (*c*) and (*d*).

256. A rectangular stick of oak wood 3.2×3.2 cm. base by 12 cm. tall floats upright with 1 cm. out of water. Find

(*a*) the specific gravity of oak; (*b*) the volume of the stick; (*c*) the weight of the stick; (*d*) the specific gravity in another way.

257. A piece of wood floats with 0.6 of its *volume* submerged. (*a*) What is the specific gravity of the body? (*b*) Under what conditions could this problem read "0.6 of its *height* submerged"?

258. A rectangular cherry block floats with 2.8 in. out of water and 5.2 in. submerged. (*a*) Find the specific gravity of cherry wood. (*b*) Must this block be rectangular?

259. Two cubic feet of a certain kind of wood weigh 100 lb. If thrown into the water, how much of it would be above the surface?

260. A stick of wood, volume 1000 cc. and specific gravity 0.55, floats in water. How many cubic centimeters are below water?

261. A stick of wood, specific gravity 0.65 and volume 300 cc., is put into a jar even full of water. (*a*) How many cubic centimeters of water will it displace? (*b*) If lowered into kerosene instead, how many cubic centimeters will it displace? (*c*) How will the weights of the displaced water and the displaced kerosene compare? (*d*) How may the specific gravity of kerosene be found from these data?

262. A cylindrical stick of wood 10 in. long sinks 6.3 in. in water. (*a*) What is its specific gravity? (*b*) To use it as a hydrometer, it is put into turpentine and sinks 7.4 in. What is the specific gravity of turpentine? (*c*) How far would it sink in copper sulphate solution, specific gravity 1.15?

263. A stick of uniform cross section, loaded at one end, floats upright in water with 30 cm. of its length submerged. In alcohol it floats with 37 cm. submerged. (*a*) Find the specific gravity of alcohol. (*b*) Find how far it would sink in sea water.

264. A wooden hydrometer of uniform section floats three quarters submerged in water. (*a*) What portion of it will be submerged if it is floated in kerosene? (*b*) What is the specific gravity of a liquid in which it floats two thirds submerged?

265. A uniform wooden hydrometer x in. long sinks y in. in water and z in. in milk. Find the specific gravity (*a*) of the wood; (*b*) of the milk.

266. When a cube of brass is floated in mercury, what fractional part of it is immersed?

267. A cube of fresh-water ice 1 m. on an edge floats in sea water with its upper face horizontal. (*a*) To what depth is the lower face immersed? (*b*) What fraction of an iceberg is above water?

268. A rectangular cake of fresh-water ice floats in sea water with its upper surface horizontal and 2 ft. above water. Find the entire height of the cake.

SPECIFIC GRAVITY OF FLOATING BODIES: SINKER METHOD

269. A piece of wood weighing 75 g. in air requires an additional force of 40 g. to submerge it. (*a*) How great is the buoyant force on the wood when submerged? (*b*) What weight of water is displaced by the submerged wood? (*c*) What, then, is the specific gravity of the wood?

270. A block of wood weighing 100 g. in air requires an additional force of 60 g. just to submerge it, so a sinker weighing 60 g. in water is tied on to it. (*a*) How great is the buoyant force on the block when submerged? (*b*) What weight of water is displaced by the submerged wood? (*c*) What, then, is the specific gravity of the wood?

271. A piece of wood weighing 150 g. in air needs an additional force of 100 g. to make it just sink. A sinker weighing 120 g. in water is tied to it. (*a*) How much greater is the total downward pull than the upward push of the water? (*b*) How much will both wood and sinker weigh in water? (*c*) What weight of water is displaced by the submerged wood? (*d*) What is the specific gravity of the wood?

272. A body weighing 50 g. in air is attached to a sinker that weighs 40 g. in water. But the sinker is too heavy, so that both together weigh 10 g. in water. Find the specific gravity of the body.

273. Eighty grams of a solid of specific gravity less than 1 is fastened to a piece of lead, and both together weigh 20 g. in water. If the lead alone weighs 50 g. in water, what is the specific gravity of the other substance?

274. A block weighing 5 lb. in air is tied to a sinker weighing 20 lb. in water, and the two together weigh 16 lb. in water. Find the specific gravity of the block.

275. A block of cork weighing 50 g. is fastened to an iron sinker weighing 216 g. The weight of both, when submerged in water, is 36 g. The sinker alone in water weighs 186 g. Find the volume (*a*) of the water displaced by both together; (*b*) of the sinker alone; (*c*) of the cork; (*d*) the specific gravity of cork; (*e*) the density of iron.

276. A block of wood weighing x g. in air is fastened to a sinker weighing y g. in air and z g. in water. Both together weigh w g. in water. Find the volume (*a*) of both together; (*b*) of the sinker alone; (*c*) of the wood alone; (*d*) the specific gravity of the wood; (*e*) the specific gravity of the sinker.

277. When a piece of cork weighing 75 g. is attached to a piece of metal weighing 275 g., the specific gravity of the

combination is 1. If the density of the cork is 0.25 g. per cubic centimeter, find the density of the metal.

278. A piece of wood weighing 50 g. in air is attached to 3 cc. of lead. Both together they weigh 4 g. in water. (*a*) What is the specific gravity of the wood? (*b*) How much heavier than it need be is the sinker?

279. Two hundred and twenty cubic centimeters of aluminum are attached to 60 g. of wood, and the combination weighs 300 g. in water. (*a*) What is the specific gravity of the wood? (*b*) How much heavier is the sinker than it need be? (*c*) How much larger in volume?

280. The specific gravity of a body lighter than water is 0.6, and it weighs 200 g. in air. If it is tied to a sinker that weighs 250 g. in water, how much will both together weigh in water?

281. A diver with his suit weighs 120 kg., and it takes 1.25 cu. dm. of lead to sink him. How many liters of water do the diver and his suit displace?

282. A diver with his suit weighs 249 lb., and it takes $\frac{1}{25}$ of a cubic foot of lead to sink him. Find the volume of man and suit expressed in cubic feet.

SPECIFIC GRAVITY BY BALANCING COLUMNS

283. In the balancing columns apparatus (Fig. 5) a column of water 60 cm. high is balanced by a column of copper sulphate solution 54 cm. high. (*a*) How do the weights of the two columns compare? (*b*) Why does the water rise higher? (*c*) What is the specific gravity of the sulphate?

284. In the balancing columns apparatus a column of water 15 in. high balances a column of oil 18 in. high. (*a*) Find the specific gravity of the oil. (*b*) How high would

a column of sulphuric acid have risen if it had been used instead of the oil?

285. In the balancing columns apparatus the water column in one tube is x in. long, and the acid column in the other tube is y in. long. (*a*) What is the specific gravity of the acid? (*b*) What is the weight of a cubic foot of the acid?

286. Find the specific gravity of alcohol by the balancing column method. Assume the necessary data, and work out to 0.8 as the result.

287. An alcohol barometer reads 508 in. when a mercury barometer is normal. Find the specific gravity of alcohol.

288. In the balancing columns apparatus a column of alcohol 40 cm. high is balanced by a column of brine 28.6 cm. high. What is the specific gravity of the brine?

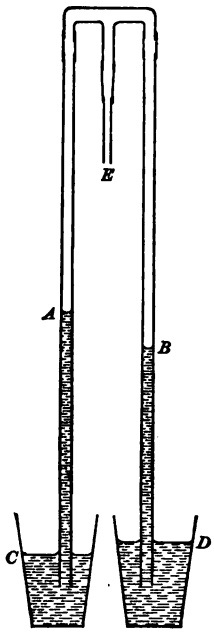

FIG. 5.

289. Into a U-tube mercury is poured until it is several centimeters over the bend on each side. Then water is poured in at one side until the water column is 50 cm. long. The height of the mercury in the other arm is now 3.7 cm. above the level of the line separating the two liquids. (*a*) Make a diagram. (*b*) Find the specific gravity of the mercury.

290. A U-tube is filled half full of water, then kerosene is poured carefully down one arm until a column of kerosene 25 in. long is formed. (*a*) Make a diagram. (*b*) Find the height of the free surface of the water above the level of the boundary between the oil and the water.

LIQUID PRESSURE

291. What is the pressure per square centimeter at a depth of (*a*) 15 cm. in water? (*b*) 15 cm. in mercury? (*c*) 60 cm. in kerosene?

292. What is the pressure per square foot at a depth of (*a*) 1 ft. in water? (*b*) 5 ft. in alcohol? (*c*) 1 mile in sea water?

293. What is the pressure per square inch at a depth of (*a*) 1 ft. in water? (*b*) 34 ft. in water? (Remember the approximate answer to *b*.)

294. Find, without figuring, the approximate pressure in water at a depth of (*a*) 68 ft.; (*b*) 100 ft.; (*c*) 300 ft.; (*d*) 1000 ft.

295. Find the pressure per square centimeter at a depth of 1 km. in the ocean.

296. Find the pressure per square inch (*a*) at the bottom of a lake 150 ft. deep; (*b*) at a depth of 150 ft. in a lake 200 ft. deep.

297. A diving bell is lowered to the bottom of a lake 100 ft. deep. What pressure must the pumps develop to force all the water out of the bell?

298. Soundings have been made in the ocean to a depth of 31,600 ft. What would be the pressure in tons per square inch?

299. A hydrometer jar contains mercury, water, and kerosene. The mercury is 5 cm. deep, the water 3 cm., and the kerosene 7 cm. (*a*) What is the pressure per square centimeter on the bottom of the jar? (*b*) If the bottom of the jar has an area of 12 cm.^{2}, what pressure does it sustain?

300. To obtain cold water, an empty jug having a mouth 2 sq. in. in area is lowered into a lake. At a depth of 120 ft.

the water forces the stopper in and the jug is filled. How great must have been the water pressure on the cork?

301. The surface area of an average-sized man is about 18 sq. ft. To what total water pressure is he subjected if he dives to a mean depth of 20 ft.?

302. A rectangular wooden prism $5 \times 5 \times 40$ cm., having a specific gravity of 0.6, stands on its square face on the bottom of a tank. The surfaces in contact are perfectly smooth. The wood is held in position while the water is poured into the tank to a depth of 50 cm. How great a force will now be needed to hold the wood in place?

303. Find the pressure on the bottom of a cubical tank 10 cm. on an edge, filled with copper sulphate solution.

NOTE. — In all problems referring to rectangular boxes or tanks the vertical surfaces having the larger area will be called *sides*, and those having the smaller area *ends*. In such problems it is best to make a diagram and put the dimensions on it.

304. (*a*) Find the pressure on the bottom of a rectangular tank 30 cm. long, 20 cm. wide, and 10 cm. deep, filled with water. (*b*) Find the pressure against one side; (*c*) against one end.

305. A rectangular tank 60 cm. long by 50 cm. wide by 40 cm. deep is filled with kerosene. Find the pressure (*a*) upon the bottom; (*b*) upon one side; (*c*) upon one end.

306. A swimming tank is rectangular, 150 ft. long, 100 ft. wide, and is filled with water to a depth of 10 ft. Find (*a*) the weight of water in it; (*b*) the pressure on the bottom; (*c*) the pressure on one side.

307. Find the pressure against the bottom and sides of a cylindrical tank 10 ft. in diameter and 20 ft. high, filled with water.

308. A covered acid tank, rectangular, 2 m. long by 1 m. wide by 50 cm. deep, is full of sulphuric acid. Find the pressure (*a*) upon the bottom; (*b*) upon the top; (*c*) upon one end; (*d*) upon one side.

309. A cubical tank 10 cm. on an edge has a pipe 1 cm. square extending from the top to a height of 30 cm. above the top. (*a*) Draw a diagram. When cube and pipe are filled with water, what is the pressure (*b*) on the bottom? (*c*) on one side? (*d*) on the top? (*e*) Would any of these answers have been different if the pipe had been 2 cm. square?

310. In problem 309, suppose the tank alone is filled with water. Find the pressure (*a*) on the bottom; (*b*) on one side; (*c*) on the top. Now assume the pipe to be filled also. Find the *additional* pressure (*d*) on the bottom; (*e*) on one side; (*f*) on the top. Find the total pressure (*g*) on the bottom; (*h*) on one side; (*i*) on the top, and compare these results with those obtained in problem 309.

311. A rectangular tank 12 cm. square and 8 cm. high has a tube, the area of which is 5 cm.^{2}, extending 22 cm. above the top of the box. Both tank and tube are full of water. (*a*) Draw a diagram. Find the pressure (*b*) on the bottom; (*c*) on one side; (*d*) on the top.

312. A rectangular tank 20 cm. square and 30 cm. tall has a tube extending from the middle point of one side up to a height 40 cm. above the top of the box. Both tank and tube are full of water. (*a*) Make a diagram. Find the pressure (*b*) on the bottom; (*c*) on all four sides; (*d*) on the top.

313. A cubical box 9 cm. on an edge is full of water. A tube enters the side of the box and extends, full of water, 41 cm. above the top of the box. (*a*) Draw a diagram. Find the pressure (*b*) on the base; (*c*) on the top. (*d*) Find the

weight of water in the box alone. (*e*) Explain the difference between answers (*b*) and (*d*).

314. A cubical box 40 cm. on an edge is filled with water. Out of the top extends a tube filled with kerosene to a height of 30 cm. (*a*) Make a diagram. What is the pressure (*b*) on the bottom? (*c*) on one side? (*d*) on the top?

315. What is the pressure against a vertical dam 300 ft. long, if the water against it is 20 ft. deep?

316. What is the pressure on a dam 60 ft. long and 30 ft. high, when the water is level with the top?

317. There is a dam 50 ft. long and 25 ft. high. The water held by this dam is 20 ft. deep. What is the lateral pressure per square foot (*a*) at the bottom of this dam? (*b*) 5 ft. from the bottom? (*c*) 10 ft. from the bottom? (*d*) 15 ft. from the bottom? (*e*) 20 ft. from the bottom? (*f*) What shape should be the section of a dam?

318. A canal lock is 12 ft. wide, 8 ft. deep, and 150 ft. long. Find the pressure on the gate when the lock is full.

319. There is a gate 3 ft. long by 2 ft. high in the side of a dam. The top of the gate is 10 ft. below the surface of the water. What pressure must the gate withstand?

320. A standpipe, *D* (Fig. 6), 70 ft. high is filled with water. It is made of steel plates each 4 ft. square. What pressure must one of these plates at the bottom of the side sustain?

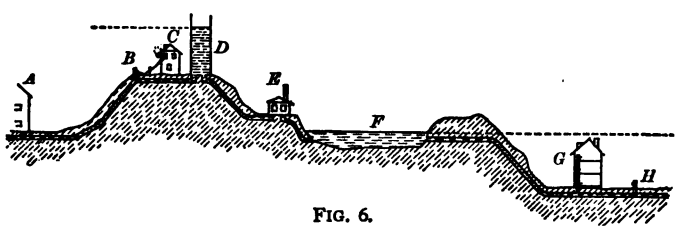

FIG. 6.

321. If water from the standpipe in problem 320 is piped to a faucet 100 ft. below the bottom of the standpipe, what will be the pressure per square inch at the faucet?

322. A storage tank 580 cm. long by 550 cm. wide by 125 cm. deep has leading from the bottom a vertical pipe 75 cm. long and 8 $cm.^2$ in cross section. The pipe is controlled by a valve at its lower end. What is the pressure on this valve when tank and pipe are full of water?

323. The surface of the water in a reservoir, F (Fig. 6), is 70 m. above a hydrant, H, in the street. What is the pressure at the hydrant?

324. The surface of the water in the town storage reservoir is 300 ft. above sea level. Find the pressure in the pipes at a point 120 ft. above sea level.

325. A house, A (Fig. 6), is supplied with water from the standpipe, D, in which the water level is 224 ft. above the ground floor of the house. Find the pressure at a faucet, (*a*) in the cellar 14 ft. below the ground floor; (*b*) in the house 20 ft. above the ground floor. (*c*) At what height would there be no pressure?

326. The head of water at a certain fire hydrant is 200 ft. (*a*) What pressure is available at the hydrant? (*b*) How high, neglecting resistance, would this pressure send the stream of water?

327. A hydraulic press is run by water from the street main. The water in the standpipe is 136 ft. above the press, the ram of which is 175 sq. in. in area. (*a*) How heavy a pressure will the press produce? (*b*) State Pascal's principle.

328. If the water pressure at a certain tap is 1500 g. per square centimeter, how much higher must be the water in the standpipe?

329. If the water gauge at a certain faucet registers 60 lb., how high is the reservoir above that point?

330. Divers can work for a short time under a pressure as great as 90 lb. per square inch. How deep would the diver have to go in water to encounter this pressure?

331. A pressure gauge on the water pipe at the top of a building reads 20 lb. and at the bottom of the building 90 lb. Find the approximate height of the building.

332. A factory is supplied with water from a tank at the top of a steel framework. The pressure at a faucet 10 ft. above the ground is 40 lb. How far above ground is the water surface in the tank?

ATMOSPHERIC PRESSURE

333. (*a*) What is the weight in grams of a column of mercury 76 cm. tall and 1 cm.^{2} in section? (*b*) If this column is supported by the weight of the atmosphere, as in a barometer, what is the atmospheric pressure per square centimeter? (*c*) How tall a column of water would be supported by this same pressure?

334. (*a*) What is the weight in pounds of a column of mercury 30 in. tall and 1 sq. in. in section? (*b*) What, then, is the atmospheric pressure in pounds per square inch? (*c*) How tall a column of water in feet would this same pressure support? (*d*) Why does not the sectional area of the column enter into the calculation?

335. When the barometer stands at 78 cm., what is the air pressure (*a*) in grams per square centimeter? (*b*) in pounds per square inch? (*c*) in centimeters of water? (*d*) in feet of water? (*e*) in inches of mercury?

336. When the barometer stands at 730 mm., what is the atmospheric pressure (*a*) in inches of mercury? (*b*) in cen-

timeters of water? (*c*) in feet of water? (*d*) in grams per square centimeter? (*e*) in pounds per square inch?

337. The atmospheric pressure at a certain time is 28 in. Express this pressure (*a*) in centimeters; (*b*) in grams; (*c*) in pounds; (*d*) in two other ways (see problem 336).

338. A pressure of 5 atmospheres means a pressure of how many pounds per square inch?

339. Compute the atmospheric pressure upon an average-sized man, the surface area of whose body is 18 sq. ft.

340. Find the pressure upon a soap bubble 4 in. in diameter.

341. The diameter of a pair of Magdeburg hemispheres is 12 cm. If the air is exhausted, what force would be required to separate them?

342. The diameter of the original Magdeburg hemispheres is 22 in. After the exhaustion was complete, it required 16 horses, 8 on each side, to separate them. Find what force they had to exert.

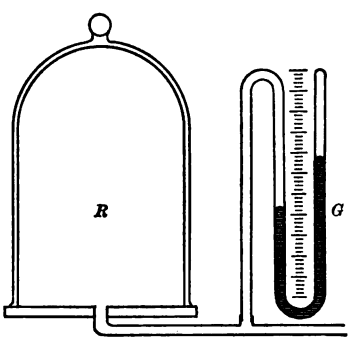

FIG. 7.

343. The air in the receiver, *R* (Fig. 7), of an air pump is rarefied so that the difference in level of the two arms of the vacuum gauge, *G*, is only 3 mm. What is the elastic force of the remaining air in pounds per square inch?

344. The opening of an ordinary bell jar, *R* (Fig. 7), is 6 in. in diameter. If this jar is placed on the plate of an air pump and two-thirds of the air removed, (*a*) what will a

barometer inside the jar register? (*b*) What force will be required to lift the bell jar from the pump plate? The pressure outside is normal.

345. The diameter of the mouth of the bell jar on an air pump is 20 cm. The jar weighs 1.5 kg. After $\frac{3}{4}$ of the air has been removed, what force will be required to lift the jar from the pump plate? The barometer stands at 29 in.

346. The diameter of the piston, *E* (Fig. 33), of a steam engine is 20 in., and steam exerts a pressure of 9 atmospheres upon it. Find the effective force in pounds, if the other side of the piston is exposed to the atmosphere.

347. If the air were throughout its height of the same density as at the surface, 0.00129 g. per cubic centimeter, how high would it have to extend to exert the normal pressure?

348. We live at the bottom of an ocean of air. (*a*) How deep would an ocean of water have to be to produce the same pressure upon us that the atmosphere normally does? (*b*) How deep an ocean of mercury?

349. A water barometer is much more sensitive than a mercury barometer. Why? During the approach of a shower a mercury barometer falls from 29.8 to 29.7 in. How far would the water barometer fall?

350. (*a*) What advantage might there be in making a barometer of alcohol? (*b*) What would it read normally? (*c*) What would it read when the mercury barometer stood at 75 cm.?

NOTE. — A difference of 900 ft. in elevation causes a difference of approximately 1 in. in barometric pressure.

351. What would the barometer read normally at Denver, 5400 ft. above the sea level?

352. The Washington Monument is 555 ft. high. Find, approximately, the difference in reading of two accurate barometers placed one at the top and one at the bottom.

353. The difference between barometer readings at the top and at the bottom of the Eiffel Tower in Paris is 1.10 in. Find, approximately, the height of the tower.

354. In making an ascent in a balloon, will the fall of the barometer during each successive 1000 ft. be greater or less than for the preceding 1000 ft.? Why?

355. A barometer is placed vertically in water with the cistern surface 80 cm. below the water surface. What would the barometer now read if the atmospheric pressure at this time were 76.2 cm.?

356. What would be the reading of a barometer placed vertically in water with its lower mercury surface 2 ft. under water? Atmospheric pressure at this time is 29.7 in.

357. What is the *total* pressure in pounds at a water depth (*a*) of 34 ft.? (*b*) 68 ft.? (*c*) 100 ft.?

358. At what depth in fresh water will the *total* pressure be 6 atmospheres?

359. In one of the common methods of building a tunnel under a river bed, compressed air is used to keep the water from coming in during construction. Neglecting the weight of the layer of earth above the tunnel, what air pressure would be needed at a depth of 60 ft. of water?

360. The stopper in a jug (full of air at normal pressure) will stand a pressure of 200 lb. How deep must the jug be sunk in fresh water to force the stopper in? Consider normal pressure to be 15 lb.

PUMP AND SIPHON

361. (*a*) At normal pressure, how far above the surface of the water in the well can the lower valve, *C* (Fig. 8), in an ordinary lift pump be? (*b*) How high can the water be raised after it has passed above the piston valve *B*?

362. The spout of a pump is 25 ft. above the water level in a well. (*a*) After the pump is filled, what force will be required to raise the piston, if its area is 8 sq. in.? (*b*) Does the required force change as the piston is raised?

363. If mercury is to be pumped, how far above the mercury surface in the cistern can the lower valve in the lift pump be (*a*) when the barometer is normal? (*b*) when the barometer registers 28 in.? (*c*) What would be the answer to (*b*) if alcohol were to be pumped?

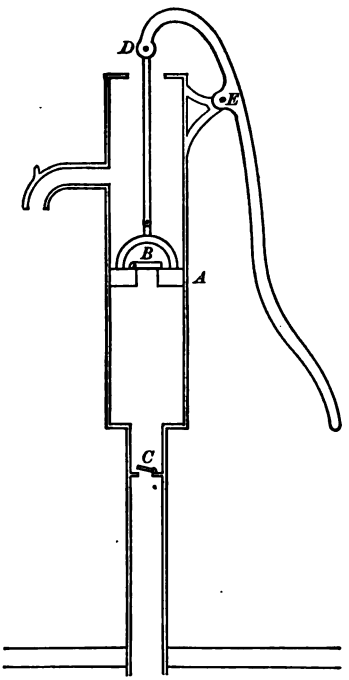

FIG. 8.

364. Mt. Washington rises about 6300 ft. above sea level. (*a*) At the summit, how high could the lower valve of a lift pump be? (*b*) How high could water be raised by this pump? (*c*) How high could it be raised by a force pump?

365. (*a*) What is meant by "the short arm of a siphon"? (*b*) In siphoning water, what is the greatest length it can have? (*c*) What is the greatest length the long arm can have?

(*d*) The least length? (*e*) If the atmospheric pressure were increased, how would it affect (*b*)? (*f*) If the liquid were heavier than water, how would it affect (*b*)? (*g*) What part does the atmosphere take in the working of the siphon?

366. (*a*) What is the greatest height, theoretically, over which water can be siphoned when the barometer stands at 28 in.? (*b*) Why is the actual height likely to be less?

367. Over how high a ridge could a siphon carry water (*a*) on a mountain 1 mi. above sea level? (*b*) in a mine half a mile below sea level?

368. (*a*) Over what height in feet can sulphuric acid be siphoned at normal pressure? (*b*) Over what height in centimeters when the barometer stands at 31 in.?

369. A hydrometer jar 1 m. deep is full of mercury. How much of this mercury can be withdrawn by means of a siphon?

DENSITY OF AIR

370. The density of air at 76 cm. and 0° C. is 1.29 g. per liter. Find the specific gravity of air referred to water as the standard.

371. Hydrogen is 0.069 times as dense as air. (*a*) Find the weight of 1 l. of it. (*b*) Find the specific gravity of it, using water as the standard.

372. The weight of 1 l. of air is 1.29 g. (*a*) What is the weight in pounds of 1 cu. ft.? (*b*) What weight of air is contained in a room 20 × 30 × 10 ft.?

373. (*a*) How large in liters would a box have to be to hold a kilogram of air at standard pressure and temperature? (*b*) If this box were rectangular with a base 1 m. square, how tall would it have to be?

374. (*a*) How large in cubic feet would a box have to be to hold 1 lb. of air at standard pressure and temperature?

(*b*) If this box were rectangular with a base of 1 sq. yd., how tall in feet and inches would it have to be?

375. (*a*) Find the weight of the air in a room 10 m. long, 6.5 m. wide, and 3 m. high. (*b*) For what pressure and temperature is this answer correct?

376. (*a*) Find the weight of air contained in a room 15 × 12 × 4 m. (*b*) Would this answer be correct for all barometric pressures and all temperatures? (*c*) Why?

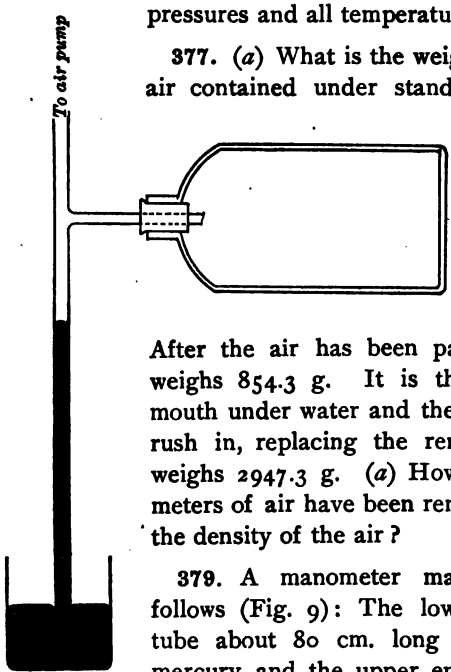

FIG. 9.

377. (*a*) What is the weight in pounds of the air contained under standard conditions in a room 30 × 20 × 9 ft.? (*b*) How much water would weigh the same as the air in this room?

378. A flask full of air weighs 857 g. After the air has been partially exhausted, it weighs 854.3 g. It is then placed with the mouth under water and the water is allowed to rush in, replacing the removed air. It now weighs 2947.3 g. (*a*) How many cubic centimeters of air have been removed? (*b*) What is the density of the air?

379. A manometer may be arranged as follows (Fig. 9): The lower end of an open tube about 80 cm. long rests in a dish of mercury, and the upper end is connected to a bottle, or other vessel, to be exhausted. As the air is pumped out from the bottle, the mercury rises in the tube. (*a*) When the mercury has risen 10 cm., what fraction of the air has been pumped out? Assume normal barometric

pressure. (*b*) When the manometer reading is 70 cm., what is the pressure in pounds per square inch inside the bottle? (*c*) What would be the reading of the manometer if all the air were removed? (*d*) Would it be possible to remove all the air? Give reasons.

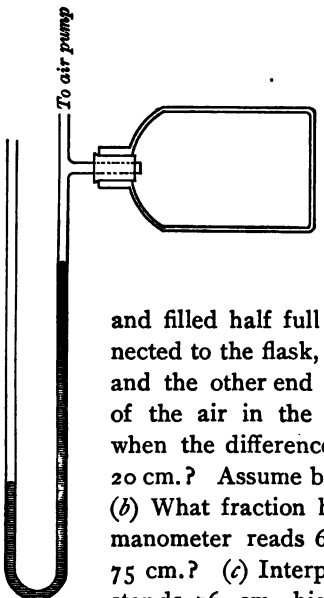

FIG. 10.

380. A manometer may be arranged as follows (Fig. 10): An open tube about 170 cm. long is bent into a U-shape and filled half full of mercury. One end is connected to the flask, or other vessel, to be exhausted, and the other end is left open. (*a*) What fraction of the air in the bottle has been pumped out when the difference in level in the manometer is 20 cm.? Assume barometric pressure to be normal. (*b*) What fraction has been pumped out when the manometer reads 65 cm. and the barometer reads 75 cm.? (*c*) Interpret the result when the mercury stands 76 cm. higher in the open arm than in the other arm and the barometer is normal.

381. Compute the density of air from the following data. The manometer described in problem 379 was used:

Manometer reading	=	60.1 cm.
Barometer reading	=	75.2 cm.
Weight of bottle after exhaustion	=	854.12 g.
Weight of bottle after air admitted	=	856.00 g.
Capacity of bottle	=	1822 cc.

382. Compute the density of air from the following data. The manometer described in problem 380 was used:

Height of mercury in closed arm	=	74.9 cm.
Height of mercury in open arm	=	6.2 cm.
Barometer reading	=	75.5 cm.
Weight of bottle after exhaustion	=	849.4 g.
Weight of bottle after air admitted	=	851.6 g.
Capacity of bottle	=	1900 cc.

BOYLE'S LAW

383. How is the volume of a certain mass of air affected (*a*) by doubling the pressure upon it? (*b*) by making the pressure half as great? (*c*) by making the pressure $\frac{3}{5}$ as great?

384. What change must take place in the pressure upon a mass of gas in order that its volume may become (*a*) half as great? (*b*) three times as great? (*c*) $\frac{4}{7}$ as great?

385. If a certain mass of gas occupies 800 cc. at a pressure of 76 cm., what would its volume be at 74 cm. pressure?

386. Five hundred cubic feet of coal gas at a pressure of 30 in. of mercury would occupy what space at a pressure of 31 in.?

387. Seven hundred and fifty liters of steam under a pressure of 15 lb. per square inch would occupy what space under a pressure of 200 lb. per square inch?

388. Into what space must 60 cu. ft. of air be compressed that its expansive force may be made twelve times as great?

389. One of the gas cylinders of an oxy-hydrogen light is 5 ft. long and 1 sq. ft. in section and contains oxygen at a pressure of 240 lb. per square inch. How many cubic feet of oxygen at normal pressure does the cylinder contain?

390. The cylindrical tank under a passenger car is 20 in. in diameter and 7 ft. long. It holds illuminating gas, forced in

under a pressure of 200 lb. per square inch. How many cubic feet will this make at standard pressure at the burners?

391. The barrel of a bicycle pump is 10 in. long. If the outlet is closed, what pressure per square inch is required to drive the plunger to within 1 in. of the bottom of the barrel?

392. How strong would a compression tank have to be if its capacity is 600 cu. in., and 5 cu. ft. of air at normal pressure is forced into it?

393. If the air in the air dome of a force pump is compressed to $\frac{1}{5}$ its normal volume, what pressure does it transmit to the water at the nozzle?

394. The air dome, *D* (Fig. 11), of an hydraulic ram has a volume of 1600 cu. in. If by the action of the ram the air in the dome is compressed to 400 cu. in., how high will the water rise in the pipe, *E*, leading from the ram to the house?

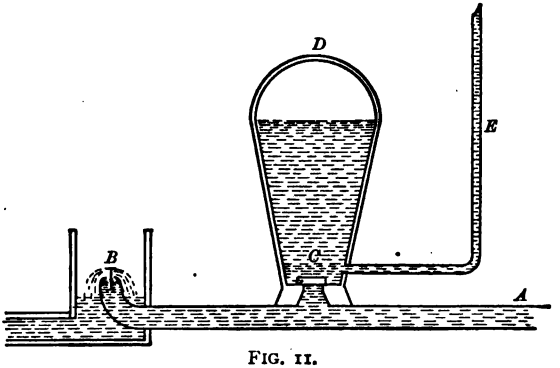

FIG. 11.

395. The greatest known ocean depth is 31,600 ft. If a tube closed at one end and containing 1000 cc. of air were lowered to this depth, open end down, what would be the volume of the air?

396. A diver descends to a depth of 102 ft. (*a*) Under what pressure does he work? (*b*) What is the density of the air in his suit? (*c*) What change would take place in the volume of a bubble of this air as it escaped and rose to the surface?

397. What will be the weight of a liter of air under a pressure of 300 in. of mercury?

398. A rectangular diving bell 14 ft. high is lowered to the bottom of a lake. (*a*) If the water rises 10 ft. inside the bell, how deep is the lake at this point? (*b*) What pressure would the compression pump have to produce to force the water entirely out of the bell?

399. A rectangular diving bell 14 ft. high is sunk to the bottom of a lake at a point where the water is 60 ft. deep. Find how high the water will rise in the bell.

400. A barometer tube 80 cm. long filled with air at 0° C. and 76 cm., is plunged open end downward into a well of mercury until the air column is 40 cm. long. How far is the open end of the tube below the surface of the mercury in the well?

401. A barometer tube 80 cm. long, filled with air under standard conditions, is plunged mouth downward into a mercury cistern until the air column is 30 cm. long. How far is the level of the mercury in the tube below that of the cistern?

402. A barometer tube 100 cm. long, filled with air under normal conditions, is pushed open end down into a mercury well until the lower end of the tube is 90 cm. below the surface of the mercury in the well. Find the length of the air column now.

403. A tube 1 m. long, of large capillary bore, closed at one end and lying horizontally, contains a column of air 30

cm. long confined by a column of mercury 20 cm. long. What does the length of the air column become when the tube is held vertically (*a*) closed end down? (*b*) open end down?

404. An open tube 100 cm. long is plunged vertically into a mercury cistern till 80 cm. is immersed, then the upper end is covered and the tube is raised till the air column at the top becomes 30 cm. long. What, now, is the difference between the two mercury levels? The barometer stands at 78 cm.

405. An open tube 80 cm. long is pushed vertically downward into a well of mercury till the lower end is at a depth of 60 cm.; then the upper end is covered and the tube is raised 10 cm. What, now, will be the difference between the two mercury levels? The barometer is normal.

406. Two cubic centimeters of air under pressure of 76 cm. is accidentally admitted to the vacuum at the top of a barometer column, and at once expands to 5 cc. (*a*) What pressure is the air now subjected to? (*b*) What will be the reading of the barometer?

BALLOONS

407. (*a*) What is the buoyant force of the air on a cubic decimeter of a substance? (*b*) Will a cubic decimeter of lead weigh more or less in vacuo than in air? (*c*) How much will it weigh? (*d*) State Archimedes' principle.

408. A kilogram of lead and a kilogram of aluminum are balanced against each other on an equal arm balance in air. Which will go down, if the contrivance is placed under an air-pump receiver and the air exhausted? Why?

409. Find the weight in vacuo of a piece of gold that weighs 1 kg. in air.

410. Under what conditions will a balloon (*a*) rise? (*b*) fall? (*c*) remain at a given elevation?

411. A balloon weighs 500 kg. and holds 100 kg. of hydrogen gas. It displaces 1450 kg. of air. Find its lifting power.

412. The capacity of a balloon is 100,000 l. The bag, car, etc., weigh 40 kg. It is filled with hydrogen (specific gravity referred to air = 0.07). What weight can it just lift from the ground?

413. The capacity of a balloon is 48,000 cu. ft. The weight of bag, car, etc., is 500 lb. The gas used is 0.4 as dense as air. A cubic foot of air weighs 1.25 oz. Find the lifting power of the balloon.

414. The capacity of a balloon is 50,000 cu. ft. Take the specific gravity of illuminating gas (referred to air) = 0.4; the specific gravity of hydrogen = 0.07, and the weight of 1 cu. ft. of air = 0.08 lb. Find what weight, including the balloon itself, can be lifted (*a*) when illuminating gas is used; (*b*) when hydrogen is used.

415. Wellman's polar expedition balloon, *America*, had a capacity of 265,000 cu. ft. and was filled with rather impure hydrogen of specific gravity 0.09 (referred to air). Using 0.081 lb. as the weight of 1 cu. ft. of air, find the maximum weight of balloon, motor, gasolene, food, men, dogs, sledges, etc., which it could carry.

CAPILLARITY

416. Will the capillary action make the actual reading higher or lower than the true reading (*a*) in a mercury barometer? (*b*) in a water barometer?

417. If water will rise by capillarity 30 cm. in a glass tube 0.1 mm. in diameter, how high will it rise in a tube 2 mm. in diameter?

418. The capillary rise of water in a glass tube 3 mm. in diameter is 10 mm. What correction should be made for capillarity in a water barometer if the tube is 1.5 cm. in diameter?

419. If alcohol rises by capillary action 6.05 cm. in a glass tube 0.2 mm. in diameter, what correction should be made in using the balancing columns apparatus (Fig. 5) if the tube holding the alcohol is 5 mm. in diameter?

420. Capillarity causes ether to rise 2.1 cm. in a glass tube $\frac{1}{2}$ mm. in diameter. Using this fact and the data given in problems 417 and 419, draw a diagram to show the heights to which water, alcohol, and ether would rise in tubes each having a diameter of 1 mm.

WORK

421. A man lifts a 20-lb. box from the floor to a shelf 6 ft. above the floor. How many foot-pounds of work does he do?

422. How many kilogram-meters of work is done in raising 250 kg. to a height of 7 m.?

423. How much work does a man do in raising a 3-lb. bucket containing $\frac{3}{4}$ cu. ft. of water from a well 30 ft. deep?

424. How much work is done in raising 50 l. of water through a height of 5 m.?

425. How much work does a 150-lb. man do in climbing Bunker Hill Monument, a height of 222 ft.?

426. A hod carrier weighing 160 lb. carries 120 lb. of brick up a ladder to a height of 40 ft. (*a*) How much work does he do in all? (*b*) How much of it is useful work?

427. When a man rolls a 250-lb. barrel up a plank into a wagon, the floor of which is $3\frac{1}{2}$ ft. high, how much work does he do against gravity?

428. The ram, *A* (Fig. 12), of a pile driver weighs 800 lb. How much work will it do on a pile head 25 ft. below, if it drives the pile 1 ft. farther into the ground?

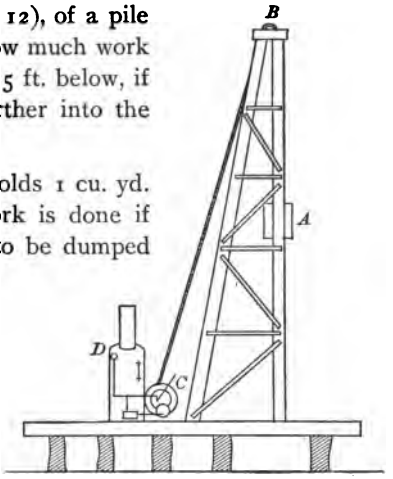

FIG. 12.

429. A steam shovel holds 1 cu. yd. of earth. How much work is done if this load is raised 20 ft. to be dumped into a car? Specific gravity of this soil is 2.0.

430. A well 6 sq. ft. in section and 40 ft. deep is to be dug. Assume the specific gravity of the removed earth to be 2.0. (*a*) From what average depth is the earth removed? (*b*) How much work will be done?

431. A horse draws a plow 3 hrs. at an average rate of 2 mi. per hour and exerts an average pull of 120 lb. How much work does he do? (Notice that 120 lb. is not the *weight* of the plow.)

432. A locomotive pulls a train for 15 min. at an average rate of 40 mi. an hour. The draw-bar pull, *i.e.* the force exerted by the locomotive, is 10 T. How many foot-tons of work is done? (Notice that 10 T. is not the *weight* of the train.)

433. How high must the 450-lb. ram of a pile driver (Fig. 12) be raised so that, in descending, it may do a foot-ton of work?

434. How long will it take a man to pump 500 cu. ft. of water from an average depth of 20 ft., if he can do 3000 ft.-lb. of work per minute?

435. The areas of the pistons of an hydraulic press (Fig. 3) are in the ratio 2 : 1000. The length of stroke of the small piston is 6 in. (*a*) How much work is done on this piston by a force of 50 lb. during 200 strokes? (*b*) What force will be exerted at the large piston? (*c*) How far will it move during the 200 strokes? (*d*) What work will it do in moving this distance?

436. The diameter of the plunger of an hydraulic press is 2 cm. and that of the ram is 40 cm. The length of stroke of the plunger is 10 cm. and the force applied is 30 kg. (*a*) How much work is done in 50 strokes? (*b*) What pressure will this produce on the ram? (*c*) How far will it move during the 50 strokes? (*d*) What work will it do in moving that distance?

HORSE POWER

437. How much work can a 3 h.p. engine do (*a*) in 5 minutes? (*b*) in 6 seconds?

438. What is the horse power of an engine that can raise 3 T. to a height of 22 ft. in 2 min.?

439. Find the horse power of a windmill that pumps 6 T. of water from a well 55 ft. deep in 10 min.

440. Assuming no friction or other losses, find the horse power of a hoisting engine that raises 100 T. of coal from the bottom of a mine shaft 2100 ft. deep in a day of 8 hr.

441. What must be the horse power of an elevator motor, if it can raise the car and its load, 2500 lb. in all, from bottom to top of a 110-ft. building in 12 seconds?

442. What is the horse power of Niagara Falls, when 700,000 T. of water passes over per minute and falls a distance of 160 ft.?

443. How many horse power are there in a waterfall 30 ft. high, over which 500 cu. ft. of water passes each minute?

444. What is the horse power of an engine that can pump 66 cu. ft. of water per minute from a depth of 150 ft.?

445. What is the horse power of an engine that will take 20 min. to pump out a cellar 50 × 20, by 10 ft. deep, full of water?

446. A city of 50,000 inhabitants consumes 4 cu. ft. of water per capita. The water is pumped from a lake to a reservoir 300 ft. above. What is the horse power of the engine at the pumping station, if it works only 10 hr. a day?

447. The weight in an old-fashioned clock weighs 11 lb., and when wound up is 3 ft. higher than when completely run down. (*a*) How much work can the clock do when it is wound up? (*b*) If the clock runs 30 hr. on one winding, what horse power does it show?

448. What is the horse power furnished by the wind when it moves a boat at the rate of 10 mi. an hour against a resistance of 500 lb.?

449. Find the horse power developed by a locomotive when it draws at the rate of 40 mi. per hour a train of cars offering a resistance of 12,000 lb.

450. What is the horse power of a locomotive that can draw a 1000-T. train of cars at the rate of 20 mi. per hour, when the resistance to motion is 30 lb. per ton of load?

451. A water motor attached to a faucet and running at full load discharges 4 cu. ft. of water per minute. The water gauge shows the pressure to be 45 lb. per square inch. If there is no loss of energy, at what horse power is the motor working?

452. How long will it take a 20 h.p. engine to raise 3 T. of coal (2240 lb. each) from a mine 400 ft. deep?

453. How quickly could a 4 h.p. hoisting engine raise the 800 lb. ram of a pile driver (Fig. 12) to a height of 30 ft.?

454. A fire engine is used to pump out a cellar 80 ft. long by 40 ft. wide by 10 ft. deep, in which the water stands to a depth of 6 ft. If the engine develops 10 h.p., how long will the work require?

455. Find the number of kilogram-meters per minute in 1 h.p. 1 m. = 39.37 in.; 1 kg. = 2.2 lb.

456. How long would it take a 20 h.p. pump to fill a standpipe of 100 cu. m. capacity standing on a hill 300 m. above the source of supply?

457. From what depth will a 5 h.p. engine raise half a ton of coal in 5 min.?

458. To what height could a 10 h.p. fire pump send 40 cu. ft. of water per minute?

459. How many tons of coal could a 5 h.p. hoisting engine raise in 30 sec. from the hold of a barge to the wharf, a height of 60 ft.?

460. (*a*) How many pounds of water per minute can a 10 h.p. fire pump raise to a height of 125 ft.? (*b*) How many cubic feet?

461. How great in pounds must be the resistance of water and air if a 9 h.p. engine can propel a motor boat at the rate of only 10 m. per hour?

462. The turbines on the *Lusitania* have a total horse power of 70,000. Against what resistance are the propellers working when the steamer is running at the maximum speed of 25 knots?

NOTE. — The expression "25 knots" usually means 25 nautical miles per hour. Consult an encyclopedia or large dictionary. 1 nautical mile = 6080 ft.

463. The most powerful locomotive in the world (1908) develops 2560 h.p. and draws a freight train 2 mi. long at the rate of 8 mi. per hour. What is the traction effort, *i.e.* the pull exerted by the engine?

464. If a 6 h.p. engine does only 150,000 ft.-lb. of work in 1 min., what is its efficiency (expressed as a per cent)?

465. What is the efficiency of a 5 h.p. engine that can raise only 120 cu. ft. of water per minute to a height of 20 ft.?

466. A 10 h.p. hoisting engine raises 100 tons of grain 40 ft. from the hold of a vessel in half an hour. (*a*) How much useful work does it do? (*b*) How much waste work? (*c*) What is its efficiency?

LEVER: FIRST CLASS

NOTE. — In all problems on the lever draw a diagram if possible.

467. A lever ABC is pivoted at B. The arms AB and BC are 8 in. and 5 in. respectively. When the proper weights are hung at A and C, the lever is horizontal. (*a*) Draw a diagram. (*b*) What must be the ratio of these weights? (*c*) If the weight at A is 40 lb., how heavy must be the weight at C? (*d*) If the weight at C is 40 lb., how heavy must be the weight at A?

468. A lever ABC is pivoted at B, and balances when weights of 4 lb. and 9 lb. are hung at A and C respectively. (*a*) Draw a diagram. (*b*) What must be the ratio of the arms AB and BC? (*c*) If AB is 36 in. long, how long must BC be? (*d*) If BC is 36 in. long, how long must AB be?

469. A bar 10 ft. long has a weight of 15 lb. suspended from the end A, and a weight of 35 lb. suspended from the end C. If the bar is to be in equilibrium, (*a*) what must be the ratio of its arms? (*b*) Where must the fulcrum be placed?

470. A boy weighing 90 lb., a stone weighing 300 lb., a crowbar 5 ft. 5 in. long: How can the boy arrange things so as to raise the stone?

471. The left-hand arm of a first-class lever is 30 in. long; the right-hand arm is 5 in. long. (*a*) What force at the end of the left-hand arm will keep in equilibrium a force of 50 lb. at the end of the right-hand arm? (*b*) What is the moment of the left-hand force? (*c*) of the right-hand force? (*d*) What relation exists between these two moments?

472. The left-hand force and its arm in a first-class lever are 50 lb. and 35 in. respectively. (*a*) What must be the moment of the right-hand force? (*b*) What must be the value of this force if its arm is 7 in.?

473. One force and its arm in a first-class lever are 10 kg. and 3 ft. respectively. (*a*) What must be the moment of the other force? (*b*) If the value of the other force is 500 g., how long must its arm be?

474. A crowbar, used as a lever of the first class, raises a 500-lb. rock 10 in. from its resting place. At the same time the hand at the other end of the bar goes down 4 ft. (*a*) What force is being exerted at this end? (*b*) How much work does this force do on the bar? (*c*) How much work is done on the rock?

475. The arms of the handle of an ordinary lift pump (Fig. 8) are 5 in. and 28 in. If the water from the well is to be lifted 1 ft. at each stroke, through how great a distance must the hand at the end of the pump handle move?

476. A coal shovel 50 in. long and holding 40 lb. of coal is supported in a horizontal position by a man, with his right hand at the end of the handle and his left hand 25 in. from that end. The center of gravity of the coal is 5 in. from the

other end. (*a*) In what direction does the right hand push? (*b*) With how much force? (*c*) In what direction does the left hand push? (*d*) With how much force?

477. The arms of a lever having the fulcrum between the two forces are 90 cm. and 20 cm. (*a*) What force applied at the end of the long arm will raise 200 kg. at the end of the short arm through a distance of 5 in.? (*b*) Through what distance must this force act? (*c*) What will be the pressure upon the fulcrum?

478. What is the mechanical advantage (*a*) of a lever having a force arm of 100 in. and a resistance arm of 20 in.? (*b*) of one having a force arm of 20 in. and a resistance arm of 100 in.?

479. A lever 12 ft. long balances when weights of 50 lb. and 10 lb. are hung at its ends. Find the position of the fulcrum.

480. A meter stick is in equilibrium with weights of 4 oz. and 5 oz. hung from the ends. Find (*a*) the position of the fulcrum; (*b*) the pressure on the fulcrum. Neglect the weight of the stick.

481. A steelyard (Fig. 13) is used to weigh a fowl. (*a*) How heavy is the fowl if, hanging half an inch from the ring that supports the steelyard, it is balanced by a 4-oz. weight hung 8 in. the other side of the support? (*b*) In general, an object weighed by a steelyard is how many times as heavy as the weight against which it is balanced?

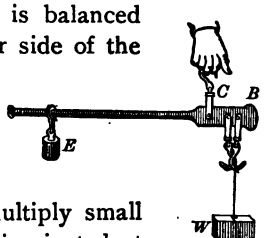

FIG. 13.

482. A lever is often used to multiply small motions. The lever ABC (Fig. 14) is pivoted at B. (*a*) If the lengths of the arms AB and BC are 20 cm. and 2 cm. respectively, how far will A move up the scale when C is pushed to the left 1 mm.? (*b*) What is the

multiplying power of the lever? (*c*) If *AB* and *BC* are 57 cm. and 1.2 cm. respectively, what is the motion of *C* when *A* moves 1.5 cm.?

483. A multiplying lever (Fig. 14) measures the expansion of a brass rod. If the arms *AB* and *BC* are 85.3 cm. and 1.8

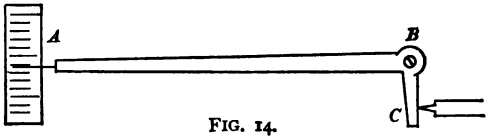

FIG. 14.

cm. long respectively, (*a*) how much does the rod elongate when *A* moves 2.3 cm. on the scale? (*b*) How much would *A* move for each millimeter elongation of the rod?

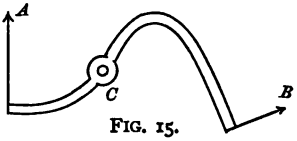

FIG. 15.

484. In machinery, levers of unusual shape are sometimes necessary. In Figure 15 the lever is pivoted at *C* and the forces act as indicated by the arrows. (*a*) What is the true arm for each of the forces *A* and *B*? (*b*) Assume their lengths to be 5 in. and 7 in. respectively, what pull will be produced at *B* by a pull of 20 lb. at *A*?

485. A claw hammer (Fig. 16) is used to draw a nail that resists with a force of 400 lb. The distance from the nail to the fulcrum is 1 in. and from the fulcrum to the hand is 10 in. What force must be exerted at the handle?

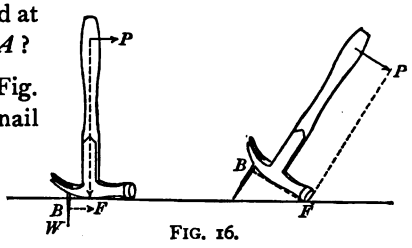

FIG. 16.

486. The handle of a claw hammer (Fig. 16) is 12 in. long, and the part of the claw that is used is 2.5 in. long. A force

of 30 lb. is needed to draw a nail. What resistance does the nail offer?

487. The effective length of the head of a claw hammer is 2 in. The handle is 15 in. long, and the nail holds in the wood with a force of 600 lb. Only 60 lb. of force is available at the end of the handle. How much too short is the handle?

488. By means of a lever of the first class a force of 200 lb. at the end of an arm 10 ft. long raises a weight of 800 lb. at the end of an arm 2 ft. long. (*a*) If the weight is raised 6 in., how much work is put into the lever? (*b*) How much is taken from it? (*c*) What is the efficiency of this machine?

489. By using a lever, a force of 150 lb. moving 80 cm. raises a weight of 600 lb. a height of 18 cm. (*a*) What is the efficiency of this machine?

LEVER: SECOND CLASS

490. In a lever of the second class it is found that the force has to move 20 cm. to make the resistance move 3 cm. (*a*) What is the ratio of force to resistance? (*b*) How much force will be needed to overcome a resistance of 80 lb.?

491. At one end of a lever of the second class, 20 ft. long, a force of 50 lb. is applied. (*a*) What is the moment of this force? (*b*) What must be the moment of the resistance? (*c*) What is the value of the resistance, if its point of application is 24 in. from the fulcrum?

492. A man uses a crowbar 6 ft. long to raise a stone weighing 400 lb., and so arranges it that the stone is 6 in. from the fulcrum, and the whole length of the bar is used. Find what force he must use, and in what direction, in a lever (*a*) of the first class; (*b*) of the second class. What is the mechanical advantage (*c*) in the first case? (*d*) in the second case?

493. A wheelbarrow measures 7 ft. from the axle of the wheel to the end of the handles. The center of gravity of the 300-lb. load is 2.5 ft. from the axle. (*a*) What force at the ends of the handles will lift the load? (*b*) What weight will the axle now be supporting? (*c*) Shift the load 6 in. nearer the axle and answer (*a*) again.

494. Reproduce Figure 17, enlarging it considerably, and add whatever letters are needed to answer these questions: In each diagram what is (*a*) the force arm? (*b*) the resistance arm? (*c*) If the center of gravity, *C*, were directly over the wheel, how much force would be needed at *A* to support the load? (*d*) Why is a truck instead of a wheelbarrow used at a freight house? (*e*) When the legs of the truck are on the ground, what part of the load do they sustain?

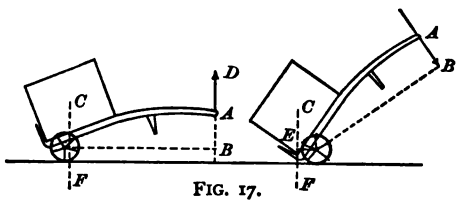

FIG. 17.

495. A force of 50 lb. applied at one end of a 12-ft. lever of the second class is to produce a tension of 450 lb. on a rope tied to the lever near the fulcrum. How far from the fulcrum is the rope to be tied?

496. The two forces of a lever of the second class are 3 lb. and 12 lb., and their points of application are 8 ft. apart. Assuming that the whole lever is used, find its length.

497. A horizontal bar pivoted at one end has weights of 10 lb. and 7 lb. acting at distances of 8 in. and 12 in. respectively from the pivot. What force will hold the bar in position if applied (*a*) 15 in. from the pivot? (*b*) 2 in. from the pivot?

498. The piston of an hydraulic press (Fig. 3) is connected to a second-class lever 30 in. long at a point 4 in. from the fulcrum. What pressure upon the piston would be produced by a force of 20 lb. at the end of the handle?

499. An hydraulic press (Fig. 3) has pistons that are 40 cm. and 3 cm., in diameter. The small piston is worked by a 27-in. lever of the second class and is attached to it at a point 4 in. from the fulcrum. What is the mechanical advantage of the whole combination?

500. The radii of the pistons of an hydraulic press are 1 ft. and 0.5 in. respectively. The press is worked by a lever, the arms of which are 2 in. and 4 ft. 2 in. respectively. (*a*) What is the full length of the lever? (*b*) What force must be applied at the end of the handle to raise a 72-T. locomotive?

LEVER: THIRD CLASS

501. A force of 25 lb. acts at a distance of 6 ft. from the fulcrum of a lever of the third class. (*a*) Will the resistance be more or less than 25 lb.? (*b*) When the force moves through 5 in., will the resistance move more or less than 5 in.? Diagram. (*c*) If the lever is 7 ft. long, how great a resistance at the extreme end can be overcome?

502. The arms of a third-class lever are 3 ft. and 16 ft. What resistance can a force of 50 lb. overcome?

503. In a lever of the third class a force of 75 lb. is applied at a distance of 4 in. from the fulcrum and overcomes a resistance of 5 lb. How long is this lever if the whole lever is used?

504. The two forces of a lever of the third class are 3 lb. and 12 lb., and their points of application are 8 ft. apart. Assuming that the whole lever is used, find its length.

505. A human forearm (Fig. 18) measures 14 in. from the elbow to the middle of the palm. If the tendon attached to the muscle of the upper arm is attached to the forearm 2 in. from the elbow, what force would it have to exert to hold a pound weight placed in the hand?

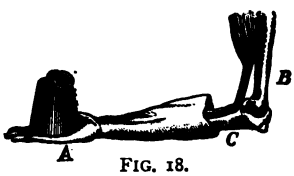

FIG. 18.

506. A ball and lever safety valve (Fig. 1) is a lever of the third class. If the valve against which the steam presses is attached to the lever at a point 4 cm. from the fulcrum, and the adjustable weight of 3 lb. is set 42 cm. still farther from the fulcrum, (*a*) how great is the pressure of the steam on the valve when it lifts the valve? (*b*) If the area of this valve is $\frac{1}{2}$ sq. in., how great is this pressure per square inch?

507. Given a lever 10 ft. long and a force of 100 lb., as a lever of which class can it be made to raise the greatest weight if the weight arm is 2 ft. long? Make a diagram of each case.

LEVER: WEIGHT OF LEVER INCLUDED

508. A uniform lever 10 ft. long and weighing 15 lb. balances upon a fulcrum placed 2 ft. from one end when a load of x lb. is hung from that end. Find the value of x.

509. An oar weighing 5 lb. has its center of gravity 4 ft. from the handle end, and rests in a rowlock at a point 2.5 ft. from the handle end. How great a force must be applied at this end to produce equilibrium?

510. A boy has a 2-lb. fishing rod 12 ft. long, the center of gravity of which is 4 ft. from the thick end. He finds the weight of the string of fish he has caught by hanging them from the thick end of the pole, then balancing the pole on a

fence rail or some other support. (*a*) If it balances at a point 16 in. from the end, how much do the fish weigh? (*b*) How did he find the center of gravity in the first place?

511. A bar 20 ft. long and of uniform weight and size has a load of 80 lb. suspended from one end, and balances if a prop is placed 2 ft. from that end. How heavy is the bar?

512. A bar 7 ft. long has its center of gravity 2 ft. from end *A*, and balances at a point 5 ft. from this end when end *B* is loaded with a weight of 15 lb. What does the bar weigh?

513. A uniform lever 22 ft. long and weighing 12 lb. balances at a point 6 ft. from one end when a 40-lb. weight is hung from this end and an unknown one is hung at the other end. How heavy is the unknown weight?

514. A uniform piece of timber 20 ft. long and weighing 200 lb. balances on a fulcrum placed 9 ft. from one end when a load of 90 lb. is placed at this end, and a keg of nails rests 1 ft. from the other end. What does the keg of nails weigh?

515. A see-saw plank 16 ft. long, weighing 20 lb., balances at a point 10 ft. from one end when a 60-lb. girl is seated 1 ft. from this end, and a boy 1 ft. from the other end. How much does the boy weigh?

516. A bar 18 ft. long, weighing 40 lb., has its center of gravity at a point 8 ft. from one end. When 200 lb. is placed at this end, it balances at a point 6 ft. from this same end, if a man throws his whole weight on a point 3 ft. from the other end. How much does the man weigh?

517. The base of a flag pole 15 ft. long rests in a socket attached under a window sill and is supported 3 ft. from the base by a brace extending up from a piazza roof below. The pole weighs 40 lb., and its center of gravity is 7 ft. from the base. A 25-lb. flag is hung with its weight concentrated at a

point 3 ft. from the end of the pole. Find (*a*) the upward pressure against the window sill; (*b*) the downward pressure upon the brace.

518. A lever of the second class is used to raise a stone weighing 500 lb. The lever is uniform, weighs 20 lb., is 10 ft. long, and supports the stone at a point 2 ft. from the fulcrum. (*a*) What force applied at the end of the lever is needed to raise the stone 6 in.? (*b*) How much work is done in raising the stone 2 ft.?

519. A 15-ft. pole balances across a fulcrum at a point 6 ft. from its large end. When 60 lb. is hung from this end and 10 lb. from the other end, the fulcrum has to be placed 2 ft. nearer the large end. (*a*) Find the weight of the pole. (*b*) Find the pressure on the fulcrum when loaded.

520. A 6-ft. crowbar balances at a point 3.5 ft. from its small end; but if a weight of 50 lb is suspended 1 ft. from this end, and 30 lb. 0.5 ft. from the other end, it balances at the middle of the bar. How heavy is the bar?

521. A horizontal lever weighing 10 lb. and having its center of gravity at a point 5 ft. from one end is weighted at this end with a load of 12 lb. Where must a man take hold of this bar to carry it in a horizontal position?

522. There is a plank 18 ft. long weighing 110 lb. A boy finds that by careful adjustment he can see-saw alone on this plank. If he weighs 90 lb., and sits 1 ft. from the end, how far from this end must the balancing point be?

523. A boy weighing 90 lb. seated 1 ft. from one end of a 110-lb. plank 18 ft. long can balance a 200-lb. man seated 2 ft. from the other end of the plank. How far from the boy's end of the plank must the fulcrum be?

524. A flag pole 25 ft. long and weighing 70 lb. balances at a point 10 ft. from one end. Find where it will balance if a 50-lb. weight is placed at each end.

525. A small rod 20 cm. long is loaded at the end A with a piece of lead and has a small hook fastened to the end B. The rod now weighs 4 oz., and its center of gravity is at a point 18 cm. from B. It may be used as a letter scale. (a) If a letter is hung at B and the rod balances at a point 16 cm. from B, how much does the letter weigh? (b) How much does it weigh if the rod balances at a point 14.4 cm. from B? (c) Where would the rod balance if a 3-oz. letter were weighed?

526. A horizontal bar 18 ft. long and weighing 30 lb., loaded with 40 lb. at one end and 50 lb. at the other, balances at a point 8 ft. from the 50-lb. end. How far from this end is the center of gravity of the bar?

527. A tapering pole 9 ft. long, weighing 30 lb., balances at a point 3 ft. from the thick end when a 25-lb. weight is hung from each end. Find the center of gravity (a) of the pole alone; (b) of the whole combination.

528. A tapering lever 16 ft. long and weighing 40 lb. balances at its middle point when a weight of 30 lb. hangs 2 ft. from its small end and another of 20 lb. hangs 1 ft. from its large end. Where would the unweighted bar balance?

529. A uniform bar, length 60 cm., weight 10 kg., lying horizontally, is hinged at one end and has a load of 40 kg. at the other end. Where must a man grasp the bar in order to support the bar and load by exerting a pull of 50 kg.? (Columbia.)

530. A derrick boom, A (Fig. 19), uniform in size, 14 ft. long and weighing 120 lb., is hinged at one end to the vertical mast, B. (a) How much work will be done in raising

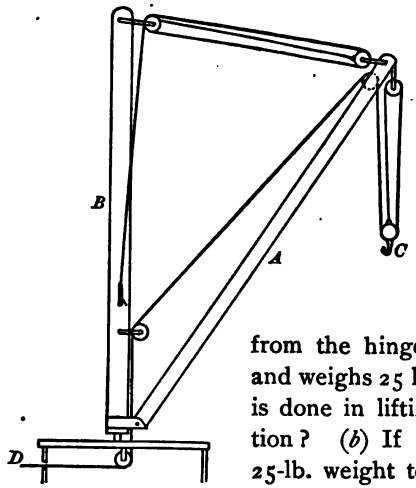

FIG. 19.

the boom from a horizontal position to one parallel to the mast? (*b*) If there is a load of 200 lb. at the outer end of the boom, how much work will be done in raising it as before?

531. A uniform trap door measures 4 ft. from the hinge to the opposite edge, and weighs 25 lb. (*a*) How much work is done in lifting it to a vertical position? (*b*) If somebody should tie a 25-lb. weight to the under side of the door at the middle of the edge opposite the hinge, how much work would be done in opening the door as before?

PULLEY

NOTE. — In all problems on the pulley draw a diagram if possible. Friction is to be disregarded unless mentioned.

532. A horse pulls a 300-lb. barrel of sugar to a loft by means of a rope and two fixed pulleys, one just above the loft door and the other near the ground. (*a*) How great a horizontal pull must the horse exert? (*b*) What is the mechanical advantage of the upper pulley?

533. A man is to raise a 200-lb. bag of sand to a platform by means of a rope and a pulley. He attaches the pulley by its hook to a beam projecting over the platform, passes the rope over the pulley, ties one end to the bag, and pulls on the other end. (*a*) How much force must he use? (*b*) If he weighs only 150 lb., how can he arrange this tackle so as to accomplish the result?

534. (*a*) What force is required with a single movable pulley to raise a weight of 180 lb.? (*b*) How far will the force move in raising the weight 10 ft.? (*c*) What is the mechanical advantage? (*d*) To which class of lever does this pulley correspond? (*e*) If a single fixed pulley were added, what is the smallest force that would raise this weight?

535. Make a series of diagrams to show all possible combinations of one, two, three, and four pulleys in a set. Under each diagram write its mechanical advantage.

536. A system of pulleys consists of a triple fixed block and a double movable block. (*a*) What force is required to raise a weight of 440 lb.? (*b*) What work is done in raising the weight 20 ft.?

537. A stone weighing 1 T. is raised by the derrick shown in Figure 19. (*a*) How great a force would have to be applied at *D*? (*b*) Through how great a distance would this force have to act to raise the stone 5 ft.?

538. Two pulley blocks, one of three pulleys, the other of two, are used to raise a weight of 300 lb. (*a*) What is the smallest force that can be used? (*b*) What would be the tension on the rope?

539. A man has two blocks of pulleys, one containing three pulleys and the other four pulleys. If he can exert a force of 110 lb., what is the greatest weight he can lift?

540. What is the smallest possible number of pulleys, and how should they be arranged, to lift a weight of 600 lb. with a force of 120 lb.?

541. A farmer who, with his boy, can exert a pull of 200 lb., finds it necessary to lift a rock weighing $\frac{3}{4}$ T. (*a*) If he uses a set of pulleys and pulls downward, how many sheaves must there be in each block? (*b*) What will be the tension on the rope?

542. With a system of pulleys, in raising a weight of 600 lb. 12 ft., a man pulls out 60 ft. of rope. (*a*) How much force does he use? (*b*) What is the arrangement of the pulleys?

543. Make a diagram to show how, by means of a set of pulleys, a horse pulling with a force of 200 lb. can move a house that, when set on rollers, offers a resistance of 1000 lb.

544. A single movable pulley weighing 5 lb. and a double fixed pulley weighing 9 lb. are used to raise a weight of 300 lb. What is the tension (*a*) upon the hook hanging from the lower block? (*b*) upon the rope? (*c*) upon the hook supporting the upper block?

545. A pulley set consisting of a triple fixed block weighing 12 lb. and a double movable block weighing 10 lb. is used to raise a 500-lb. weight. What is the tension (*a*) on the hook that hangs from the lower block? (*b*) on the rope? (*c*) upon the hook that supports the upper block?

546. What is the efficiency of a set of pulleys if a force of 60 lb., acting through 100 ft., raises a weight of 480 lb. only 10 ft.?

547. With a triple fixed block and a double movable block a man weighing 130 lb. is just able to lift 500 lb. What is the efficiency of the system?

548. The efficiency of a set of pulleys is only 75 %. How much force should be applied if, acting through 80 ft., it is to raise a load of 420 lb. a distance of 16 ft.?

WHEEL AND AXLE

NOTE. — In all problems on the wheel and axle draw a diagram if possible. Friction is to be disregarded unless mentioned.

549. In order that 100 lb. may just support 500 lb., what must be the ratio (*a*) of the arms of a first-class lever? (*b*) of the radii of a wheel and axle? (*c*) of the diameters? (*d*) of the circumferences?

550. In a wheel and axle, if the radius of the wheel is 2 ft. and the radius of the axle is 3 in., what force is required at the circumference of the wheel to raise a weight of 400 lb. attached to a rope wound around the axle?

551. The axle or barrel of an old-fashioned windlass (Fig. 20) is 6 in. in diameter, while the lever arm is 1 ft. 9 in. long. (*a*) What force at the end of the arm will draw a bucket of water weighing 30 lb. from a well? (*b*) How great is the mechanical advantage?

FIG. 20.

552. The spokes of the pilot wheel of a boat are 2.5 ft. long, and the axle around which the rudder ropes are wound is 6 in. in diameter. What force must be applied to steer the boat when the rudder resistance is 250 lb.?

553. The circumferences of a wheel and axle are 8.1 ft. and 1.5 ft. respectively. (*a*) What weight on the axle can be supported by a force of 60 lb. on the wheel? (*b*) What weight on the wheel can be supported by a weight of 60 lb. on the axle?

554. The rope wound around the barrel of a windlass 20 cm. in diameter holds a weight of 60 kg. If the windlass is turned by a crank 90 cm. long, (*a*) what force will be required to hold it? (*b*) through how many *feet* will this force move in raising the weight 6 ft.?

555. A windlass (Fig. 20) is used to raise a bucket of water from a well 30 ft. deep. The diameter of the barrel is 8 in., the length of the crank is 20 in., and the force applied is 12 lb. (*a*) How heavy a load can be raised? (*b*) How much

work is done in bringing it to the surface of the ground? (*c*) Through how many feet does the end of the handle move?

556. The axle of a windlass is 4 in. in diameter; how long must the crank be, if it takes only 15 lb. to raise a 70-lb. bucket of water?

557. It takes 75 lb. to lift a 500-lb. rock, using a simple wheel and axle, the crank of which is 1 ft. 8 in. long. (*a*) How much rope is wound in by one revolution of the crank? (*b*) How much work is done?

558. A windlass is used to raise from a well a bucket of water weighing 40 lb. For each turn of the handle the bucket is raised 15 in., and only 10 lb. of force is used. How long must the crank be?

559. A house set on rollers is being moved by a capstan (Fig. 21). The capstan bar is 12 ft. long and the horse at the end of it pulls with a force of 180 lb. The rope tied to the house winds around the capstan barrel, which is 15 in. in diameter. (*a*) What force is exerted upon the house? (*b*) What work is done upon it in moving it 25 ft.?

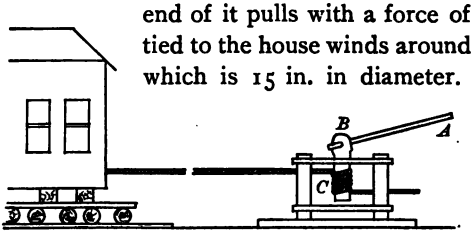

FIG. 21.

560. In moving a building, a horse attached to the end of a capstan bar 8 ft. long walks in a circle at a rate of 2 mi. per hour. The capstan barrel to which the building is attached is 1 ft. in diameter. (*a*) How far will the building move in 10 minutes? (*b*) If the horse exerts a pull of 100 lb., how much work does he do in this time? (*c*) At what rate in horse power does he work?

561. A capstan with four levers or handspikes is used to raise a ½-T. anchor. The barrel of the capstan is 15 in. in diameter, and the handspikes, measured from the axis, are each 5 ft. long. (*a*) If four men are pushing, one from the end of each handspike, how hard must each one push to raise the anchor? (*b*) How far will each man walk in raising the anchor 90 ft.? (Neglect the fact that the anchor is part of the time in the water.)

562. A wrought-iron anchor weighing 1500 lb. is to be raised by six men using a capstan, the barrel of which is 18 in. in diameter. Each man uses a handspike 4 ft. long, and pushes at a point 3 in. from the end of it. How much force must each man apply (*a*) to raise the anchor to the surface of fresh water? (*b*) to raise it above the water?

563. Four men are raising an anchor by means of a capstan, the barrel of which is 2 ft. in diameter. They use two 5-ft. handspikes, one man at the end and one 15 in. from the end of each. (*a*) If each man pushes with a force of 60 lb., how much work does each do in raising the anchor 30 ft.? (*b*) How great is the strain on the rope? (*c*) Is this also the true weight of the anchor?

564. The diameters of a wheel and axle are 40 in. and 6 in. respectively. The force is applied to the end of a rope wound around the axle. (*a*) How great must it be to raise a 50-lb. weight tied to the end of a rope wound in a groove on the circumference of the wheel? (*b*) How great is the mechanical advantage? (*c*) Through how great a distance would the force have to move in order to raise the weight 20 ft.? (*d*) In what practical contrivances is the force applied at or near the axle, as in this case?

565. Study a sewing machine and notice especially the relation of pedal, pitman rod, crank, large wheel, belt, and small wheel. The large wheel of the sewing machine (Fig. 22) is

13 in. in diameter, and the crank connected to the pitman rod moves through a circle 5 in. in diameter. When the pedal applies a force of 30 lb. to the crank, what force is transmitted to the belt on the rim of the wheel?

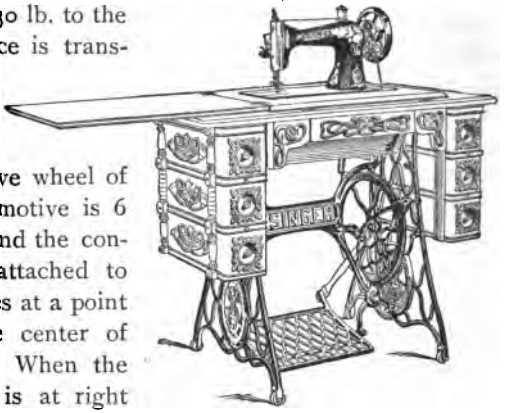

FIG. 22.

566. The drive wheel of an express locomotive is 6 ft. in diameter and the connecting rod is attached to one of the spokes at a point 12 in. from the center of the wheel. (*a*) When the connecting rod is at right angles to this spoke, and a force of 2000 lb. is applied to it, with what force will the engine tend to move the train? (*b*) Find the mechanical advantage.

567. The drive wheel of a freight locomotive is 4.5 ft. in diameter, and the connecting rod is attached to one of the spokes at a point 18 in. from the axis of the wheel. (*a*) When the connecting rod is at right angles to this spoke, and a force of 2000 lb. is applied to it, with what force will the engine tend to move the train? (*b*) Why is this locomotive better adapted to freight traffic than the one described in problem 566?

568. It requires a force of 80 lb. at the rim of a wheel 3 ft. in radius to move a $\frac{1}{2}$-T. weight attached to a rope wound around the axle 4 in. in diameter. What is the efficiency of this machine?

569. It takes six men, each applying a force of 40 lb. at the end of a 5-ft. handspike, to raise an anchor weighing 800 lb.

and attached to a capstan barrel 2 ft. in diameter. Find the efficiency of this capstan.

570. A windlass (Fig. 20), the barrel of which is 7 in. in diameter, is worked by a crank 25 in. long. Friction reduces its efficiency to 80%. How much force will be needed to raise a bucket of water weighing 60 lb.?

PARALLEL FORCES

571. Two boys are pulling in the same direction on the tongue of a cart, one with a force of 30 lb., the other with a force of 18 lb. (*a*) What is the resultant of these two pulls? (*b*) What pull in the opposite direction will produce equilibrium?

572. (*a*) Find the value and direction of the resultant of a force of 150 lb. and another of 180 lb., both acting north upon the same point. (*b*) Find value and direction of the equilibrant of these forces.

573. Two boys are pulling on a rope in opposite directions, each with a force of 40 lb. (*a*) What is the resultant of the two forces? (*b*) What is the tension on the rope? (*c*) If one of the boys were replaced by a hook in the wall, and the other boy pulled as before, what would be the tension on the rope?

574. Two boys are pulling on a rope, one east with a force of 50 lb., the other west with a force of 40 lb. (*a*) What is the resultant of these two forces? (*b*) What single force, and acting in what direction, is needed to produce equilibrium?

575. There are two forces, 20 lb. and 14 lb., acting in the same direction on a bar, and at right angles to its length. The distance between their points of application is 17 ft. Find the magnitude, direction, and point of application (*a*) of the equilibrant of these forces; (*b*) of the resultant of them.

576. (*a*) Find the value, position, and direction of the equilibrant of two parallel forces of 25 lb. and 10 lb. respectively, if they act in the same direction and are applied at points 21 ft. apart. (*b*) Find the value, point of application, and direction of the resultant of these two forces.

577. Find the value, point of application, and direction of the equilibrant and resultant of two parallel forces of 90 lb. and 24 lb. respectively, acting in the same direction, with points of application 9.5 ft. apart.

578. A force of 11 lb., applied 6 cm. from the N. end of a bar running N. and S., acts E. Another force of 15 lb., applied 12 cm. from this same end, acts W. Find the value, direction, and point of application of the single force that will produce equilibrium.

579. A man and a boy carry on a pole 10 ft. long a load of 200 lb. Where must the load be placed if the boy is to bear only 45 lb. of it?

580. A cart horse and a carriage horse are to haul a wagon that requires 400 lb. of force to move it. How shall they be hitched to the wagon so that the cart horse shall pull $\frac{3}{5}$ of the load?

581. Arrange a 3-horse whippletree so that each horse shall pull $\frac{1}{3}$ of the load.

582. Two men, A and B, hold the ends of a horizontal pole 12 ft. long. On the pole is a load of 300 lb. hanging 4 ft. from A. How many pounds does each carry?

583. Two men carry a load of 320 lb. by means of a pole resting on their shoulders. The men are 8 ft. apart, and the load is 3.5 ft. from the stronger man. How many pounds does each man carry?

584. A 20-ft. ladder weighing 60 lb. has its center of gravity at a point 8 ft. from the base. Two men carry it by each taking hold of the round 1 ft. from his end. What weight does each carry?

585. Two horses are hitched side by side, one at each end of a horizontal bar 4 ft. long, which is attached, at a point 1.5 ft. from one end, to the pole of a wagon. How hard must each horse pull to overcome a resistance of 320 lb.?

586. A uniform horizontal beam 30 ft. long and weighing 900 lb. rests in a socket at each end. A weight of 1000 lb. is hung 6 ft. from one end of the beam. How great is the pressure at each socket?

587. A painter's ladder, 18 ft. long and weighing 50 lb., has its center of gravity at a point 7 ft. from one end. The ladder is swung horizontally by two sets of pulleys each attached 1 ft. from the end. When a painter weighing 150 lb. stands at a point 10 ft. from the large end of the ladder, what weight does each set of pulleys support?

588. A bridge 90 ft. long, weighing 150 T., is supported equally by stone abutments at the two ends. A locomotive weighing 60 T. stands on the bridge, with its center of gravity at a point 30 ft. from the east end. Find the total weight supported by each abutment.

589. Two forces of 10 lb. and 12 lb. act up upon a bar at points 3 in. and 11 in. respectively from the right end; another force of 15 lb. acts down at a point 5 in. from this same end. Find the value, direction, and point of application of the force that will produce equilibrium.

590. A rod 10 in. long has the following forces acting upon it: at distances of 1 in., 5 in., and 9 in. from the left end, forces of 12 lb., 4 lb., and 7 lb. respectively acting down; at distances of 2 in. and 7 in. forces of 10 lb. and 5

lb. respectively acting up. Find the value, direction, and point of application of the equilibrating force.

591. A rod running E. and W. has forces of 3 lb. and 5 lb. acting S. at points 2 in. and 7 in. respectively from the W. end; and forces of 2 lb., 4 lb., and 6 lb. acting N. at points 0 in., 4 in., and 9 in. respectively from the same end. (*a*) What is the value of the equilibrant? (*b*) What is its direction? (*c*) How far from the W. end is its point of application?

592. Two trip scales are placed side by side with a triangular prism on the left-hand pan of each. A meter stick is laid across the prism and the scales moved so that the stick is supported at the 10 cm. and 90 cm. divisions. After counterpoising the scales, weights of 10, 20, 50, 100, and 200 g. are placed at the 20, 40, 50, 60, and 80 cm. divisions respectively. What will be the additional pressure upon the left pan of each balance?

593. A spy glass is made of three hollow brass cylinders, each uniform and 8 in. long. The weights of these parts are 2 lb., 1.5 lb., and 1 lb. Neglecting the slight overlapping of the cylinders, find the center of gravity of the spy glass when extended.

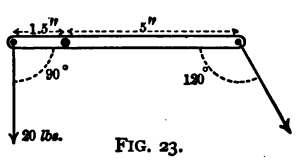

FIG. 23.

594. Reproduce Figure 23 to scale, and find the value of the force necessary to produce equilibrium.

COUPLES

595. Two parallel and opposite forces, each of 15 lb., act upon a body with their lines of direction 20 in. apart. (*a*) Find the value, point of application, and direction of a single force, if there is one, which will produce equilibrium. (*b*) A force of 30 lb. has its point of application between the

given two, 2 in. from one of them and opposite to this one in direction; find the value, point of application, and direction of a single force, if there is one, which will now produce equilibrium.

596. There is an N. and S. couple having an arm 20 ft. long and forces of 300 lb. each. Show by diagram how this couple can be balanced (*a*) by another N. and S. couple; (*b*) by an E. and W. couple.

597. The arm of an E. and W. couple is 5 ft. long and the forces are 72 lb. each. Show by diagram how this couple can be balanced by another E. and W. couple having forces (*a*) of more than 72 lb. each; (*b*) of less than 72 lb. each.

598. Two forces, each of 60 lb., are applied to a body so that they act in opposite directions along lines 4 ft. apart. Show two possible cases of equilibrium in which these forces are balanced by two other forces of 36 lb. each.

599. A couple having an arm of 50 in. and forces of 225 lb. each is balanced by another couple having an arm 5 ft. long. Show by diagram the value and direction of the forces of this second couple.

600. A uniform door 8 ft. high and 4 ft. wide weighs 60 lb. and swings on hinges placed 1 ft. from the top and 1 ft. from the bottom. (*a*) If properly hung, what is the vertical pressure on each hinge? (*b*) How great is the horizontal *pull* upon the upper hinge? (*c*) How great is the horizontal *push* against the lower hinge?

601. A gate weighing 40 lb. is hung on hinges 4 ft. apart. The distance from the center of gravity of the gate to the vertical line passing through these hinges is 5 ft. The load is equally divided between the two hinges. (*a*) What vertical pressure must each hinge sustain? (*b*) What horizontal push or pull?

602. A rectangular gate 3.5 ft. high and 5 ft. wide has its center of gravity at its geometrical center. It hangs on hinges placed 3 in. each from top and bottom. The horizontal pull or push on each hinge is 70 lb. (*a*) How heavy is the gate? (*b*) If properly hung, how much of the weight is supported by each hinge?

603. A 20-ft. plank weighing 112 lb. rests against a wall with its upper end 16 ft. above the ground. Assuming that the wall is perfectly smooth, find how hard the plank presses horizontally against it.

604. A ladder 17 ft. long leans against a smooth wall with its top 15 ft. above the ground. The weight of the ladder, 40 lb., is concentrated at a point 7 ft. from its base. Find the friction of the ground that keeps the bottom of the ladder from slipping horizontally.

605. A 30-ft. ladder, the center of gravity of which is 12 ft. from its base, rests against a smooth wall with its base 10 ft. from the wall. It pushes horizontally against the wall with a force of 20 lb. How heavy is the ladder?

606. A 40-ft. ladder weighing 150 lb. leans against a smooth wall with its base 10 ft. from the wall. The horizontal push against the wall is 15 lb. How far from the bottom of the ladder is its center of gravity?

607. A ladder 30 ft. long and weighing 100 lb. leans against a smooth wall with its base 10 ft. from the foot of the wall. The center of gravity of the ladder is 13 ft. from its base. A painter weighing 150 lb. stands on the ladder 6 ft. from the top. Find the horizontal pressure against the house.

COMPOSITION OF CONCURRENT FORCES AND VELOCITIES

608. Find the resultant of two forces of 8 and 10 units if they act upon a body (*a*) in the same direction and at the same point; (*b*) in opposite directions but at the same point; (*c*) in the same direction but at points 36 in. apart; (*d*) at the same point but in directions at right angles to each other.

609. (*a*) Two horses attached to a load pull in the same direction with forces of 150 lb. and 180 lb. What is the resultant pull? (*b*) If these horses pull with the same force as before, but at an angle of 60° with each other, what is the resultant pull?

610. Find the resultant and equilibrant of two forces, 30 and 40, making with each other an angle of (*a*) 20°; (*b*) 45°; (*c*) 100°; (*d*) 160°.

611. Find the resultant of two forces of 16 and 12 units which act on a body at the same point but in directions at right angles to each other.

612. Two concurrent forces act at an angle of 75° with each other. The value of one force is 15 lb., and of the other 20 lb. What single force could be substituted for them to produce the same effect?

613. A force of 50 lb. acts N. upon a body and another force of 60 lb. acts E. upon the same point. (*a*) What is the resultant of these two forces? (*b*) What are the value, point of application, and direction of a single force which would balance these two forces?

614. A telegraph pole at a street corner has wires leading from it to the south and to the east, exerting a pull of 300 lb.

in each of those directions. (*a*) In what direction horizontally should a guy wire act to relieve the strain on the pole? (*b*) How hard should it pull?

615. A body moves E. at a constant rate of 20 mi. per hour and S. at a constant rate of 30 mi. per hour. What is its actual rate of motion?

616. A flag is hauled down 65 ft. from the mast of a vessel which moves forward 100 ft. during this time. (*a*) Represent the path of the flag. (*b*) Find the length of this path.

617. A balloon ascends at the rate of 20 ft. per second and at the same time is blown horizontally by the wind at a rate of 15 ft. per second. What is its actual rate of motion?

618. (*a*) What is the actual velocity of a sailboat that is carried east 4 mi. per hour by the wind and northeast 2 mi. an hour by the tide? (*b*) In what direction will it move?

619. A football is kicked at the same time by two boys, one to send it E. with a force of 50 lb., the other S.S.E. with a force of 40 lb. In what direction will the ball move?

620. A man riding on an electric car at the rate of 10 mi. per hour, jumps off at right angles with a velocity of 10 ft. per second. Show by diagram the resultant velocity and the direction.

621. As a train moving at the rate of 40 mi. per hour passes a station, a mail bag is tossed out at right angles with a velocity of 10 ft. per second. Find the direction and velocity of its motion at the instant it is thrown.

622. A boy who can row 4 mi. per hour in still water starts to row straight across a stream flowing 3 mi. per hour. He does not take account of the current, and reaches the other side in half an hour. Where does he land?

623. Find the value and direction of the force that can be resolved into two forces, one, 60 kg., acting vertically, and the other, 70 kg., acting horizontally.

624. What must be the value and direction of the force that can be resolved into two others, one, 120 lb., acting N., and the other, 80 lb., acting 40° E. of N.?

625. Find the value and direction of the resultant of three forces — 5 lb. acting N., 10 lb. acting N.E., and 15 lb. acting E.

626. A traveling crane lifts a heavy casting at the rate of 2 ft. per second, and at the same time travels lengthwise of the shop at the rate of 5 ft. per second. (*a*) Find the resultant velocity of the casting. (*b*) If at the same time the crane carries the casting across the shop at the rate of 3 ft. per second, what is the resultant velocity of the three motions?

627. Find the value and direction of the force that will put the following three concurrent forces in equilibrium: 20 lb. acting N., 25 lb. acting 40° W. of N., and 35 lb. acting 30° E. of N.

RESOLUTION OF CONCURRENT FORCES AND VELOCITIES

628. Given a force of 10 units acting E. Resolve this into three distinct sets of components, each set in a different color if possible.

629. Given a force of 10 units acting E. Resolve this into two forces, one acting N.E. and the other S.E.

630. Given a force of 10 units acting E. Resolve this into two forces, one acting S. and the other N.E.

631. Given a force of 10 units acting E. Resolve this into two forces, one of which shall be 7 units acting S.E.

632. Given a force of 10 units acting E. Resolve this into two components, one of which has a value of 4 units and acts at an angle of 110° with the given force.

633. Given a force of 10 units acting E. Resolve this into two components acting at right angles with each other, one of which shall be twice as great as the other.

634. Resolve a force of 300 lb. into two components acting at an angle of 100° with each other, one of which shall be three times as great as the other.

635. Find the southerly and easterly components of a wind that is blowing from the S.E. at a rate of 30 mi. per hour.

636. A carriage road makes an angle of 25° with the horizontal. When a carriage moves up this slope at a rate of 6 mi. per hour, how far would it move horizontally and how far vertically in 10 min.?

637. The mules at the end of the tow line of a canal boat pull with a force of 400 lb. at an angle of 20° with the direction of the boat. (*a*) How much of this force moves the boat forward? (*b*) How much is at right angles to the desired direction? (*c*) Try the effect of lengthening the tow line so that it makes an angle of only 10° with the direction of the boat.

638. A pair of horses is pulling a load that offers a resistance of 500 lb. If one pulls 20° to the right and the other 25° to the left of the straight-ahead direction, how hard must each pull to move the load straight ahead?

639. A picture weighing 30 lb. is hung evenly by a cord that passes over a single hook. The two parts of the cord are equal in length and make an angle of 50° with each other. What is the tension on the cord?

640. A force of 20 lb. acting N. is balanced by two other forces, one acting 40° E. of S., and the other 30° S. of W. Find the magnitude of each force.

641. A weight of 50 lb. is supported by two cords fastened to hooks in the ceiling, each cord making an angle of 30° with the ceiling. Find the tension on each cord.

642. A weight of 200 kg. is held by two cords, one making an angle of 70° with the horizontal, and the other an angle of 40°. Find the tension on each cord.

643. A 150-lb. man is sitting in a hammock in such a way that the rope at the head of the hammock makes an angle of 50° with the piazza post to which it is tied, and the other rope makes an angle of 60° with its post. How strong must each rope be?

INCLINED PLANE

NOTE. — Friction is to be disregarded unless mentioned.

644. A mass of 80 lb. is to be raised by means of a frictionless inclined plane which has a length of 10 ft., a base of 8 ft., and a height of 6 ft. (*a*) How large a force parallel to the incline will it take to move the mass 1 ft. up the incline? (*b*) To move it 3 ft. up the incline? (*c*) How much work will be done in moving the mass the whole length of the incline? (*d*) How large a force, parallel to the base, will it take to move the mass up the incline? (*e*) How much work will be done by this force in moving the mass the whole length of the incline? (*f*) How much work will be done in raising the mass vertically up to the top of the incline?

645. If the base in problem 644 becomes 6 ft. and the height 8 ft., all other conditions remaining the same, what will be the answer to questions (*a*) and (*d*)?

646. The length of an inclined plane is 5 ft., its height 3 ft., its base 4 ft. What fraction of the weight of a body

must the force be which can move the body up the incline by acting (*a*) parallel to the incline? (*b*) parallel to the base? Neglect friction. (*c*) What is the mechanical advantage in each case?

647. The length of an inclined plane is 5 ft., its height 3 ft., and its base 4 ft. The weight raised can be how many times the force used if the force acts (*a*) parallel to the incline? (*b*) parallel to the base?

648. A force of 60 lb. acting parallel to the incline prevents a 300-lb. barrel of sugar from rolling down an inclined plane. What is the ratio of the length to the height of the plane?

649. (*a*) How much work would be done in lifting a barrel weighing 200 lb. to a platform 3 ft. high? (*b*) How much force would it take to roll this barrel up to the platform by means of a plank 10 ft. long, if the push were parallel to the plank? (*c*) In this case, how much work would be done? (*d*) How much force would it take if the push were parallel to the ground? (*e*) In this case, how much work would be done?

650. A cable car weighing 2 T. is moving up a track which rises 1 ft. for every 10 ft. of length (called a 10% grade). What is the pull on the cable?

651. A weight of 125 lb. is to be drawn up an incline that rises 4 ft. for every 14 ft. of length. Neglecting friction, what force parallel to the incline will be needed?

652. A ball weighing 20 lb. is placed on an inclined plane, the length and height of which are 25 ft. and 2 ft. respectively. (*a*) What force acting parallel to the incline will keep the ball from rolling down? (*b*) What force parallel to the base will keep it from rolling down?

653. The base and length of an inclined plane are 15 ft. and 17 ft. respectively. What force acting up the incline will just sustain a box weighing 175 lb. placed on the incline?

654. A skid l ft. long rests with one end on a cart h ft. high. (*a*) What is the smallest force that will roll a barrel weighing w lb. into the wagon? (*b*) How much work will be done?

655. A body weighing 300 lb. is pulled 30 ft. up an incline that rises 1 ft. in 20 ft. of incline, *i.e.* a 5 % grade. The friction amounts to a force of 70 lb. How much work is done (*a*) against gravity? (*b*) against friction?

656. An inclined plane rises 2 ft. for every 12 ft. of horizontal distance. A packing case weighing 200 lb. is resting on the plane, kept from sliding down by the friction between the case and the plane. How great is the friction?

657. How long a plank will be needed for a man to roll an iron safe on trucks into a wagon 35 in. from the ground with a pull of 700 lb.? The safe weighs 1.5 T.

658. A weight of 200 lb. rests on an inclined plane of the following dimensions: length 20 ft., base 16 ft., height 12 ft. (*a*) With what force does the weight tend to move down the incline? (*b*) What pressure does it exert against the plane?

659. A box of soap weighing 70 lb. rests upon a 10-ft. plank that reaches from the ground to a wagon floor 3 ft. high. The friction keeps the box from sliding down. (*a*) How great is the friction? (*b*) How great is the pressure between the box and the plank?

660. The length and height of an inclined plane are 15 ft. and 3 ft. respectively. If it takes a force of 350 lb., acting parallel to the incline, to raise $\frac{1}{2}$ T., what is the efficiency of the machine?

661. The approach to a bridge rises 1 ft. in 7 ft. of length. Assuming a loss of 25 % (efficiency 75 %), how heavy a load could a team of horses, that can exert a pull of 500 lb., draw up on to the bridge?

SCREW

NOTE. — Friction is to be disregarded unless mentioned.

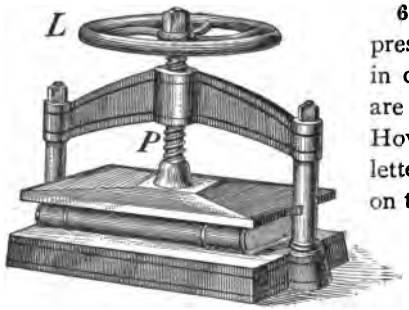

FIG. 24.

662. The wheel on a letter press, *L* (Fig. 24), is 25 in. in circumference, and there are 5 threads to the inch. How much pressure on the letter book will a 40-lb. force on the wheel produce?

663. A vise (Fig. 25) having 6 threads to the inch is used to hold a gas pipe. The end of the lever, *B*, turns through a circle 2 ft. in diameter. What pressure is exerted on the pipe by a force of 20 lb. at the end of the lever?

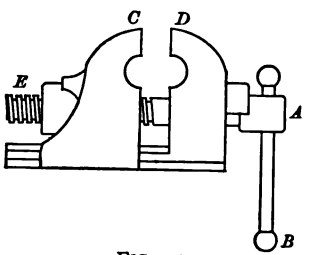

FIG. 25.

664. A jackscrew (Fig. 26) is used to raise a weight of 1½ T. The bar of the jackscrew extends 2.5 ft. out from the center of the spindle, and there are two threads to the inch on the screw. What force must be applied at the end of the bar to raise the weight?

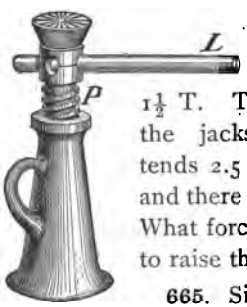

FIG. 26.

665. Six jackscrews are set horizontally against the sill of a building to move the building side-

ways. On each jackscrew the bar used is 3 ft. long and extends to the middle of the spindle. The pitch of the screw is $\frac{1}{2}$ in. A man at each jackscrew has to apply a force of 60 lb. to move the building. What resistance does the building offer?

666. A lifting jack (Fig. 26) having a pitch of $\frac{1}{2}$ in. is worked by a lever, the outer end of which passes through a circle 9 ft. in circumference. (*a*) How heavy a load may be raised by a force of 20 lb.? (*b*) How much work is done in lifting this load 1 ft.? (*c*) How many turns would the operator have to make? (*d*) Through what total distance would the force act?

667. The screw of a cider press has 4 threads to the inch, and is worked by a lever of such length that a force of 20 lb. produces a pressure of $1\frac{1}{4}$ T. on the apples. (*a*) How long is the lever? (*b*) What is the mechanical advantage of the press?

668. The lever of a bench vise (Fig. 25) is 1.1 ft. long, measured as a radius, and a force of 60 lb. is available at the outer end of it. (*a*) What should be the pitch of the screw if a metal block is to be held between the jaws by a pressure of 7000 lb.? (*b*) What is the mechanical advantage of this machine?

669. The lever in a jackscrew extends 2 ft. out from the center. (*a*) If a man exerting a pressure of 100 lb. is to lift *one end* of a car weighing 30 T., how many threads to the inch must there be? (*b*) What is the pitch?

670. The end of the handle of a lifting jack travels a circle 12 ft. in circumference, and the pitch of the screw is $\frac{3}{8}$ in. But it takes a force of 25 lb. at the end of the handle to raise a load of 2 T. Find the efficiency of this machine.

671. The lever arm of a screw is 2 ft. 1 in., measured out from the center, and the pitch is $\frac{1}{2}$ in. The efficiency of this screw is only 70%. Find the force necessary to produce a pressure of 1 T.

COMPOUND MACHINES

672. A hogshead of molasses is being rolled up the 20-ft. gangplank of a steamboat, the deck of which is 6 ft. lower than the wharf. A rope, one end of which is tied to the top of the gangplank, runs down, passes under the barrel, then up to two men on the wharf at the head of the gangplank. What force must each man exert if the hogshead weighs 500 lb.?

673. At the top of an inclined plane which rises 3 ft. in 5 of incline, is a windlass which has a barrel 10 in. in diameter and a crank 12 in. long. If a force of 50 lb. is applied at the end of this crank, what weight can be drawn up the incline if the efficiency of the combination is 60%?

674. The derrick shown in Figure 19 is to be used in lifting a 1500-lb. block of granite. The rope passes from *D* to a windlass which has a barrel 4 in. in diameter and a crank 18 in. long. How much force must a man apply at the handle of the crank to lift the stone?

675. In moving a building a horse pulls with a force of 100 lb. at the end of a capstan bar 6 ft. long; on the capstan barrel, which is 14 in. in diameter, is wound a rope which passes to a system of 3 fixed and 3 movable pulleys attached to the house. Draw a diagram. What force is exerted on the house? Take the efficiency as 80%.

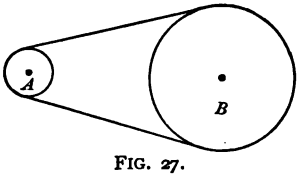

FIG. 27.

676. The pulley *A*, (Fig. 27), on one shaft is 4 in. in diameter. It is belted to a pulley, *B*, 12 in. in diameter on another shaft. If the first shaft makes 900 revolutions per minute, how many will the second shaft make?

677. The pulley on one shaft is 3 in. in diameter and makes 980 R.P.M. At what rate will a 7-in. pulley to which this is belted revolve?

678. The wheel connected to the pedal of a sewing machine (Fig. 22) is 45 in. in circumference, and the head wheel to which it is belted is 9 in. in circumference. At every revolution of the head wheel 1 stitch is taken. How many stitches does the machine take for each up and down motion of the pedal?

679. For turning wood, a lathe should run at a minimum speed of 1000 R.P.M. If the countershaft from which the power is taken is revolving 400 times per minute, what should be the relative sizes of the pulley on this shaft and the pulley on the headstock of the lathe, if this speed is to be attained?

680. The 3-in. pulley on the shaft of a small magneto (dynamo) bears against the rim of the 15-in. fly wheel of a gas engine which runs at the rate of 400 R.P.M. At what rate does the magneto run?

681. The armature shaft of a motor has a 3-in. pulley which is belted to a 20-in. pulley on an overhead shaft; a 4-in. pulley on this overhead shaft is belted to the 24-in. fly wheel of a churn. The speed of the motor is 1600 R.P.M. What is the speed (*a*) of the 20-in. pulley? (*b*) of the 4-in. pulley? (*c*) of the churn? (*d*) Obtain the result in (*c*) in a single operation.

682. The main shaft passing the whole length of a factory has at one end a 12-in. pulley which is belted to the 10-ft. fly wheel of an engine. This fly wheel revolves once a second. (*a*) How many R.P.M. does the main shaft make? (*b*) Two of the machines belted to this shaft are to run at speeds of 400 and 1500 R.P.M. respectively. What size pulleys on the machines and on the main shaft would accomplish this result?

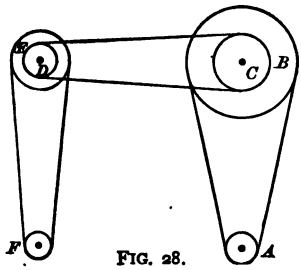

FIG. 28.

683. In Figure 28, *A* is the pulley on the shaft of a motor. *B* and *C* are pulleys on the countershaft overhead. *F* is a pulley on the headstock of a lathe, and *E* and *D* are pulleys on the countershaft above. If the circumferences of *A*, *B*, *C*, *D*, *E*, and *F* are 16, 69, 26, 25, 27, and 13 in. respectively, at what speed will the lathe run when the motor speed is 1800 R.P.M.?

684. A cogwheel, *A* (Fig. 29), having 60 teeth on its circumference meshes into a smaller cogwheel, *B*, having 12 teeth on its circumference. (*a*) When the large wheel makes 2 revolutions, how many does the small one make? (*b*) How many would the large one make while the small one makes 2 revolutions?

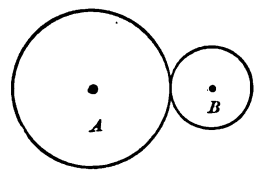

FIG. 29.

685. The rear wheel of a bicycle is 28 in. in diameter; the rear wheel sprocket has 8 teeth and the pedal sprocket 22 teeth. How far does the rider go forward for 1 revolution of the pedals?

686. A cogwheel, *D* (Fig. 30), called a driver, having 40 teeth on its circumference, meshes into an idler, *I*, having 50 teeth on its circumference, which in turn meshes into another cogwheel, *F*, called a follower, having 8 teeth on its circumference. (*a*) For 1 revolution of the driver, how

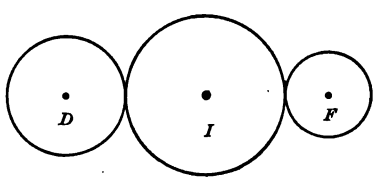

FIG. 30.

many revolutions does the follower make? (*b*) Assume the same conditions, except that the idler has 10 teeth, and answer (*a*). (*c*) What is the purpose of the idler?

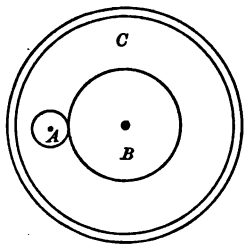

FIG. 31.

687. Figure 31 represents the speed-reducing gear of a modern electric car motor. *A* is the pinion attached to the motor armature and has 14 cogs. *B* is the gear wheel attached to the car wheel, *C*, and has 67 cogs. (*a*) Find the speed reduction ratio. (*b*) If the wheel, *C*, is 33 in. in diameter, find the number of revolutions the motor makes in carrying the car 100 ft. (*c*) Do armature and car wheel revolve in the same or in opposite directions?

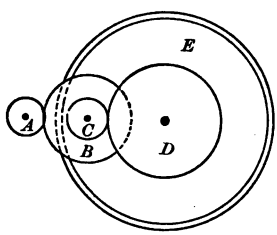

FIG. 32.

688. Car motors were formerly run at a much higher speed, and were geared down as shown in Figure 32. *A* is the pinion on the armature and *E* is the car wheel. The number of cogs on *A*, *B*, *C*, and *D* are 16, 80, 25, and 100 respectively. (*a*) Find the speed reduction ratio. (*b*) Do the car wheel and the armature revolve in the same or in opposite directions?

FRICTION

689. It takes a force of 5 lb. to draw a sled weighing 40 lb. along a horizontal surface. What is the coefficient of friction?

690. If a force of 2 lb. is required to draw a sled weighing 30 lb. over a frozen lake, (*a*) what is the coefficient of

friction? (*b*) what force would be required if the sled carried a 90-lb. boy?

691. If it takes a force of 25 lb. to push a 90-lb. case of shoes across the floor, (*a*) what is the coefficient of friction? (*b*) What would the coefficient be if this case were twice as heavy?

692. The locomotive referred to in problem 463 weighs 205 T., all of which rests upon the 16 drivers. (*a*) What is the coefficient of sliding friction of iron upon iron if this engine can exert a pull of just 60 T. without slipping? (*b*) What is the coefficient of rolling friction for the whole train if this traction effort of 60 T. moves on a level track a train weighing 10,000 T.?

693. A stone drag with its load weighs 500 lb., and rests on a horizontal surface upon which its coefficient of friction is 0.4. With how much force must a pair of horses pull to move this load?

694. The coefficient of rolling friction of a railroad train drawn along a level track is 0.009. What pull would an engine have to exert to haul a train weighing 2000 T.?

695. The coefficient of sliding friction of iron on iron is 0.21. What force can a locomotive weighing 100 T. exert before slipping, assuming the entire weight to rest on the drive wheels?

696. How heavy a cake of ice can be dragged across a floor by a force of 12 lb. if the coefficient of friction in this case is 0.06?

697. The coefficient of iron on brass is 0.18. What pressure must a smooth-jawed pair of forceps exert upon a piece of brass to hold it against a pull of 60 lb.?

698. How much work would be done by a horse in drawing a sleigh weighing with its occupants 350 lb., over a horizontal road 1 mi. long? Take the coefficient of friction of steel on hard snow as 0.02.

699. A block of cherry wood slides with uniform velocity down a smooth pine board 40 in. long, one end of which is 8 in. above the other. Find the coefficient of friction of cherry on pine.

700. A skid 10 ft. long rests against a platform with one end 3 ft. higher than the other, and supports a body weighing 140 lb. (*a*) How great must the friction be to keep the body from sliding down? (*b*) How great must the coefficient of friction be?

701. A plank 10 ft. long rests with one end on the ground and the other on the tailboard of a wagon 4 ft. above the ground. A box of groceries slides down the plank with uniform motion. What fraction of the weight of the box is the friction between the rubbing surfaces?

702. The coefficient of friction between pine and oak is 0.2. How high should one end of an oak plank 20 ft. long be raised that a pine box may just slide down when once started?

703. A body weighing 90 lb. is drawn up an inclined plane which rises 4 ft. for every 5 ft. of incline. (*a*) Assuming there is no friction, what force parallel to the incline is required to draw the body up? (*b*) What pressure does the body exert against the incline? (*c*) If the coefficient of friction is $\frac{1}{3}$, what force will be required?

704. A body weighing 20 lb. rests on an inclined plane, the length, base, and height of which are 10 ft., 8 ft., and 6 ft. respectively. (*a*) What pressure does the body exert against the plane? (*b*) Assuming that there is no friction, what force

parallel to the incline is required to keep the body from sliding down? (*c*) If the coefficient of friction is 0.3, what force will be required?

705. A packing case weighing 60 lb. is pulled up an inclined platform 100 ft. long that rises 2.5 ft. in 10 of incline. If this platform were horizontal, it would require 12 lb. of force to draw the case along. (*a*) How much force will be required as things are? (*b*) How much work will be done in drawing the case to the top of the platform?

706. A weight of 30 lb. is drawn 10 ft. up an inclined plane which has a base of 12 ft. and a height of 9 ft. The coefficient of friction is 0.15. (*a*) How much work is done? (*b*) If the weight had been lifted vertically to the same height, how much work would have been done?

GRAVITATION

707. If the attraction between two masses of 1 g. each at a distance of 1 cm. is 1 unit, what will the attraction be if one of the masses is increased (*a*) to 2 g.? (*b*) to 5 g.? (*c*) if one of the masses is doubled and the other trebled?

708. If the attraction between two masses of 1 g. each is 1 unit at a distance of 1 cm., what would the attraction be at a distance of (*a*) 2 cm.? (*b*) 3 cm.? (*c*) 12 cm.? (*d*) $\frac{1}{4}$ cm.? (*e*) 1 mm.?

709. If the attraction between two masses of 1 g. each at a distance of 1 cm. is 1 unit, what will be the attraction (*a*) between masses of 4 g. and 2 g. at a distance of 2 cm.? (*b*) between masses of 1 kg. and 500 g. at a distance of 1 m.? (*c*) if one mass is trebled and the other doubled, and the distance between them reduced to 3 mm.?

710. If the attraction between the earth and a bag containing sugar is 1 lb., what would be the attraction

(*a*) if the bag contained twice as much sugar? (*b*) if instead of increasing the mass of sugar, the mass of the earth were doubled without changing its size? (*c*) if the mass of both earth and sugar were doubled?

711. How would it alter the attraction between the earth and the moon (*a*) if the mass of each were doubled; (*b*) if the mass of the moon were doubled and that of the earth were halved?

712. What would be the weight of a body that weighs 50 lb. now, if the mass of the earth were sixteen times and the radius were four times what they are?

713. (*a*) If the mass of the earth were increased $\frac{1}{8}$, how would it affect the weight of our standard kilogram weight? (*b*) Suppose, instead, that the kilogram weight were carried $\frac{1}{8}$ farther away from the center of the earth than it is now, how much would it weigh?

NOTE. — The radius of the earth is approximately 4000 mi.

714. A body weighs 1000 lb. at the earth's surface. (*a*) What would it weigh 4000 mi. above? (*b*) 1000 mi. above? (*c*) 4 mi. above?

715. How far above the surface of the earth must one of our pound weights be taken that it may weigh 10 oz.?

716. A ton of ore at the surface of the earth would weigh how much (*a*) 1000 mi. below the surface? (*b*) 2000 mi. below? (*c*) 4 mi. below?

717. If a mass of 1 lb. were carried to a planet where it weighs 20 oz., what would the acceleration due to gravity be at that place?

718. The mass of Mars is $\frac{1}{8}$ that of the earth, and its radius is $\frac{1}{2}$ that of the earth. (*a*) How much would one of our pound weights weigh on that planet? (*b*) If Mars is

habitable, how high could one of our athletes jump there if he holds a record of 6 ft. here? (*c*) How far would a freely falling body fall in the first second of its fall?

719. A body that weighs 50 lb. at a point halfway between the center and the surface of the earth will weigh how much at a point 4000 mi. above the surface?

720. At what two points, one above the surface of the earth and the other below, would a body have the same weight?

PENDULUM

NOTE. — Give answers in the English system unless otherwise specified. The length of a seconds pendulum is approximately 39.1 in. or 100 cm.

721. Find in meters the length of a pendulum that makes one vibration (*a*) in 2 sec.; (*b*) in 10 sec.; (*c*) in a quarter of a second.

722. Find in inches the length of a pendulum that vibrates once (*a*) in 3 sec.; (*b*) in half a second.

723. Find the length of a pendulum whose period of vibration is 0.8 sec.

724. Find the length of a pendulum which makes (*a*) 5 vibrations per second; (*b*) one fifth of a vibration per second.

725. What is the length of a pendulum which makes 80 vibrations per minute?

726. How long must a pendulum be to vibrate 40 times a minute?

727. A plumb bob suspended by a thread from an upper window sill in a tall building swings within 2 ft. of the ground and makes 12 vibrations per minute. How high above the ground is the window sill?

728. What are the relative lengths of three pendulums that vibrate in 1, 2, and 6 sec. respectively?

729. What are the relative lengths of two pendulums, one of which makes 20 vibrations while the other makes 25?

730. One pendulum is 20 in. long and vibrates 5 times as fast as another. Find the length of the other.

731. Find in centimeters the length of a seconds pendulum at a place where $g = 980$ cm. per second per second.

732. Find in inches the length of a seconds pendulum at a place where $g = 980$.

733. Find the length of a seconds pendulum at Boston where $g = 32.16$.

734. Find the time of vibration of a pendulum the length of which is (*a*) 16 m.; (*b*) 0.25 m.

735. Find the time of vibration of a pendulum (*a*) 156.4 in. long; (*b*) 10 ft. long; (*c*) $\frac{1}{2}$ m. long.

736. A plumb bob is suspended from the ridgepole of a barn, and just clears the floor below. The distance is 70 ft. How long will it take the bob to swing from one end of its arc to the other?

737. A pendulum 20.35 m. long hangs from the inside of a cathedral dome. How many seconds are required for one vibration?

738. Find the time of vibration of a simple pendulum 100 cm. long at a place where $g = 980$.

739. Find the time of vibration of a simple pendulum 39.1 in. long at a place where $g = 32.16$.

740. How many vibrations per minute will be made by a clock pendulum (*a*) 25 cm. long? (*b*) 351.9 in.?

741. How many vibrations per minute will be made by a pendulum 30 ft. long?

742. How many vibrations per minute will be made by a pendulum 2 m. long?

743. At a place where $g = 980.2$, how many vibrations per hour will a 20-in. pendulum make?

744. If the length of a seconds pendulum at a certain place is 99.6 cm., what is the value of g at that place?

745. Find the value of g at a place where a pendulum 22 in. long makes 200 double vibrations in 5 min.

UNIFORM MOTION

746. How far will a train go in 1 hr. 20 min., if it travels at an average rate of 30 mi. per hour?

747. A steamer travels at a uniform rate of 24 knots. How many nautical miles will it cover in a day of 24 hr.? (See note, problem 462.)

748. A train traveling at the uniform rate of 60 mi. per hour goes how many feet in 1 sec.? (Remember this result.)

749. In what time will a train moving at a uniform rate of 40 mi. per hour travel a distance of 12 mi.?

750. Ocean steamers are now built that can travel at the rate of 25 knots. How long would it take one of these liners to cross from New York to Liverpool, a distance of 2880 nautical miles? (See note, problem 462.)

751. The sound of an explosion is heard 6 sec. after its occurrence, at a place 6500 ft. distant. Find the rate at which sound travels, assuming its velocity to be uniform.

752. With what uniform velocity will a body move 20 ft. in $\frac{2}{5}$ sec.?

ACCELERATED MOTION

NOTE. — Give answers in the English system unless otherwise specified. Disregard the resistance of the air. $g = 32$ ft. per second per second, or 980 cm. per second per second.

753. A train starts from a station, and 5 sec. later is going at the rate of 10 ft. per second. (*a*) What is its average speed? (*b*) Find its acceleration per second per second, assuming it to be uniform.

754. An electric car is moving at the rate of 5 mi. per hour. The power is turned on so that in 50 sec. it is going at the rate of 10 mi. per hour. (*a*) What is the average velocity for the 50 sec.? (*b*) What is the acceleration per second per second, assuming it to be uniform?

755. A ball rolling along a level floor is going at a rate of 5 ft. a second, when it begins to roll down a smooth incline. It reaches the bottom of the incline 4 sec. later and is going at the rate of 45 ft. per second. (*a*) What is its average velocity down the incline? (*b*) What is its acceleration? (*c*) How long is the incline?

756. A train, just as it reaches a down grade, is going at the rate of 20 mi. per hour. At the foot of the grade, 40 sec. later, its rate is 50 mi. per hour. (*a*) What is its average velocity down the grade? (*b*) What is its average acceleration? (*c*) How long is the grade?

757. A car moving at the rate of 30 mi. per hour is uniformly retarded by application of the brakes and stops in 20 sec. (*a*) What is its average velocity during this time? (*b*) What is its acceleration? (*c*) How far does it run after the brakes are applied?

758. A train starts from a station and gains speed at a uniform rate of 2 ft. per second. What will be its velocity at the end of half a minute?

759. A steel ball rolls down a smooth inclined plane with an acceleration of 3 ft. per second per second. What velocity will it have at the end of 8 sec.?

760. What velocity will a body have after falling 10 sec.? Give answer (*a*) in feet per second; (*b*) in meters per second.

761. If a carpenter drops a hammer from the staging of a high building, what velocity in meters per second will it have when it strikes the ground 5 sec. later?

762. With what velocity will a falling body be moving (*a*) at the beginning of the fourth second of its fall? (*b*) at the end of the fourth second?

763. A ball thrown straight up into the air reached the starting point again in 4 sec. (*a*) How many seconds was it going up? (*b*) How many seconds was it coming down? (*c*) What final velocity did it have coming down? (*a*) With what initial velocity must it have been thrown up?

764. With what velocity must a ball be thrown up that it may return in 6 sec.? Give answer (*a*) in the English system; (*b*) in the metric system.

765. With what initial velocity must a bullet be shot up so that it shall rise for just 6 sec.?

766. How long will it take a falling body to acquire a velocity (*a*) of 224 ft. per second? (*b*) of 224 m. per second?

767. A sled starts from rest at the top of a hill, and when it reaches the bottom of the hill 4 min. later is going at the rate of 20 ft. per second. Assuming the acceleration to be uniform, find the acceleration (*a*) per second per minute; (*b*) per second per second; (*c*) per minute per minute.

768. A sled after coasting down one hill immediately starts up another one with a velocity of 18 ft. per second and comes

to rest 2 min. later. Assuming the retardation to be uniform, find its value per second per second.

769. An electric car is moving at the rate of 5 ft. per second. When the power is turned on, giving it an acceleration of 3 ft. per second, how fast will it be moving in 6 sec.?

770. A stone is thrown down from a window of a high building, with a velocity of 10 ft. per second, and strikes the ground 3 sec. later. What velocity does it have on striking?

771. A train running at the rate of a mile a minute is slowed down at a uniform rate of 1.1 ft. per second. What will be its velocity at the end of 1 min.?

772. A croquet ball is started along the grass at a rate of 2 m. per second and slows down at a uniform rate of 30 cm. per second. What will be its velocity at the end of 5 sec.?

773. A ball is thrown up with an initial velocity of 100 ft. per second. What will be its velocity at the end of 3 sec.?

774. A bullet is shot upward with a muzzle velocity of 1200 ft. per second. What velocity will it have at the end of 1 min.?

775. Find the distance traveled in $\frac{1}{4}$ min. by a train that starts from rest with an acceleration of 60 cm. per second per second.

776. An express train slowing down at the rate of 1.5 ft. per second per second is brought to a stop in 40 sec. In what distance is the train stopped?

777. An electric car moving at the rate of 40 ft. per second is retarded by the brakes and comes to rest in 30 sec. Find (*a*) the acceleration; (*b*) the distance in which the car was stopped.

778. If a ball rolling down an inclined platform starts from rest and increases in speed at the rate of 12 cm. per second per second, how far will it roll in 9 sec.?

779. How far will a body fall in 6 sec., starting from rest?

780. A freely falling body starting from rest will fall how far (*a*) in 4 sec.? (*b*) in 5 sec.? (*c*) in the fifth second?

781. A ball is dropped down a mine shaft. (*a*) How far will it fall during the sixth second? (*b*) How deep is the shaft if the ball does not reach the bottom till the end of 9.5 sec.?

782. A drop of water falls from a gutter spout, and 1 sec. later another one falls. How many meters apart will they be after the first drop has fallen 3 sec.?

783. A ball is thrown over a tree and reaches the ground 5 sec. later. (*a*) With what velocity is it thrown? (*b*) How tall is the tree?

784. An arrow shot vertically upward rises for 6.5 sec. (*a*) How far does it rise? (*b*) How far above the ground is it at the end of the third second?

785. A body starts from rest and moves horizontally with a constant acceleration of 5 ft. per second. How long will it take it to travel 360 ft.?

786. How long will it take ballast dropped from a balloon 1 mi. high to reach the ground?

787. How long would it take a stone to fall from the top of Bunker Hill Monument, 222 ft. high?

788. A stone is dropped over the top of a cliff 256 ft. high, and the sound when it strikes the rocks below is heard 4.24 sec. later. Find the velocity of sound.

789. What acceleration would cause a body starting from rest to travel a distance of 100 ft. in 5 sec.?

790. A steamboat starts from rest, and moving with a constant acceleration, requires 2 min. to cover the first 300 ft. (*a*) What is its acceleration per second per second? (*b*) What is its velocity at the end of 5 min.?

791. A body is thrown down with a velocity of 2 m. per second. How far will it fall in 3 sec.?

792. A body thrown down from a captive balloon with a velocity of 20 ft. per second strikes the ground in 5 sec. (*a*) How high up is the balloon? (*b*) With what velocity does the body strike the ground?

793. If a stone were thrown down from the top of the Eiffel Tower, 1000 ft. high, with a velocity of 20 ft. per second, how long would it be in reaching the ground?

794. A package on a freight elevator, which is descending at a uniform rate of 8 ft. per second, is pushed off and falls to the basement 80 ft. below. How long is it in falling?

795. (*a*) With what initial velocity must a ball be thrown down from a cliff to reach the rocks 150 ft. below in 3 sec.? (*b*) With what velocity will it strike?

796. A marble is pushed down an inclined plane with an initial velocity of 5 ft. per second and rolls down a distance of 400 ft. in 10 sec. What is its acceleration?

797. An elevator is moving upward at a uniform rate of 12 ft. per second when a package is pushed off and reaches the bottom of the shaft in 3 sec. (*a*) How far above the bottom of the shaft was the package pushed off? (*b*) With what velocity does it strike?

798. A balloon is rising at a uniform rate when a package is lost overboard and falls to the ground 6100 ft. below in

20 sec. At what rate was the balloon ascending when the accident occurred?

799. What velocity will a body have after falling 400 ft.?

800. If a stone fell from a balloon a mile high, with what velocity would it strike the ground?

801. What velocity would a raindrop have in falling from a cloud 1000 ft. above the earth? The actual velocity is probably less than 50 ft. per second. Account for this discrepancy.

802. (*a*) With what velocity must a stone be thrown up to pass over a telegraph pole 70 ft. tall? (*b*) With what velocity will it strike the ground again?

803. (*a*) With what velocity must an arrow be shot upward that it may rise to the top of the Washington Monument, 555 ft.? (*b*) How many seconds would it require to reach the top?

804. Through what height must a stone fall to gain a velocity of 200 m. per second?

805. A body dropped over the edge of a cliff strikes the rocks below with a velocity of 80 ft. per second. How high is the cliff?

806. A ball is thrown vertically upward with a velocity of 96 ft. per second. (*a*) How far will it rise? (*b*) How long will it be in the air?

807. An arrow is shot vertically upward with a velocity of 128 ft. per second. (*a*) How high will it rise? (*b*) Where will it be at the end of 6 sec.? (*c*) What will be its velocity at the beginning of the third second?

808. A bullet is shot vertically upward from an air gun with a velocity of 40 ft. per second. (*a*) How far will it rise? (*b*) How far would it rise if the velocity were doubled?

809. A train moving at the rate of 60 mi. per hour can be stopped by air brakes in a distance of 900 ft. Find the retardation caused by the brakes.

810. A trolley car is running at the rate of 30 mi. per hour. When the air brakes are applied, it is uniformly retarded and brought to a stop in 750 ft. Find (*a*) the retardation caused by the brakes; (*b*) the time required to stop the car.

811. A body slides down a frictionless inclined plane the length and height of which are 100 ft. and 10 ft. respectively. The acceleration due to gravity at this place is 980 cm. per second per second. Resolve this acceleration into two components, one along the plane and the other perpendicular to it. (*a*) Find graphically and by calculation the acceleration of the body down the incline. (*b*) Find the distance the body will slide down the incline during the first second.

812. How far would a body slide down a frictionless inclined plane in 3 sec. if the plane had a height of 40 ft. and a length of 500 ft.? (*b*) What velocity would it have at the end of 5 sec.?

813. There is a frictionless inclined plane 400 ft. long and 100 ft. high. Two bodies are placed at the top and one is allowed to slide down the incline, while the other falls vertically. (*a*) How much sooner will the falling body reach the base of the plane? (*b*) How much greater velocity will it have at that instant?

814. What would be the acceleration due to gravity at a place where a freely falling body falls only 15 ft. the first second?

PROJECTILES

815. A ball is thrown horizontally from the top of a tower with a velocity of 150 ft. per second. It reaches the ground in 3 sec. (*a*) Where does it strike the ground? (*b*) How tall is the tower?

816. A ball is thrown horizontally from the top of a tower with a velocity of 150 ft. per second and strikes the ground at a distance of 750 ft. from the foot of the tower. (*a*) How soon does it strike? (*b*) How tall is the tower?

817. A ball is thrown horizontally from the top of a tower 200 ft. tall with a velocity of 150 ft. per second. (*a*) How soon does it strike the ground? (*b*) Where does it strike?

818. From the rear of a train moving at the rate of 30 mi. an hour a package falls to the ground 6 ft. below. How far will it move along the track before striking the ground?

819. A sailor drops his jackknife from the masthead of a ship to the deck 70 ft. below. The ship is sailing at the rate of 15 mi. an hour. How far from the foot of the mast does the knife fall?

820. A projectile is fired from a gun 15 m. above the water, with a muzzle velocity of 800 m. per second. If the gun is aimed in a horizontal direction and strikes a ship just at the water line, how far away is this ship?

821. A ball is thrown horizontally from a tower 256 ft. high and strikes the ground 800 ft. from the foot of the tower. (*a*) How far does it go horizontally during the third second? (*b*) How far vertically during this second?

822. With what horizontal velocity must a bullet be shot from a height of 100 ft. that it may have a horizontal range of 4000 ft.?

823. A ball is thrown from center fielder to the catcher 200 ft. distant at an average horizontal speed of 50 ft. per second. How high in the air does it go?

824. A ball is shot obliquely upward from a cannon on the shore, with an average horizontal velocity of 2000 ft. per second. It hits a target placed on the water at a distance of 4 mi. How high in the air does it go? The target and the mouth of the cannon are each 5 ft. above the water.

825. Construct a curve to show the path of a stone thrown horizontally from a tower 44.1 m. high, with a horizontal velocity of 14.7 m. per second. Use a scale 1 cm. = 4.9 m. or $\frac{1}{2}$ in. = 4.9 m.

826. Construct a curve to show the path of a ball thrown obliquely upward from the ground with a vertical velocity of 128 ft. per second and a horizontal velocity of 64 ft. per second. Use a scale $\frac{1}{4}$ in. = 16 ft.

MOMENTUM

827. If a force of 50 lb. produces a certain acceleration upon a body weighing 200 lb., what acceleration would a force of 150 lb. produce upon the same body?

828. A locomotive is able to accelerate a train at the rate of 6 in. per second per second. What acceleration could it produce if the train were made (*a*) $\frac{1}{4}$ as heavy? (*b*) 5 times as heavy?

829. A certain force produces an acceleration of 200 cm. per second per second upon a mass of 50 g. Upon what mass can this force produce an acceleration of 1000 cm. per second per second?

830. A horse starting an empty wagon weighing 800 lb. can increase its speed at the rate of 1.5 ft. per second per second. When the wagon has a load of flour in it, he can, with

the same effort, produce an acceleration of only 0.5 ft. per second per second. How much does the load of flour weigh?

NOTE. — Problems similar to the last four, but involving absolute units, will be found on page 108.

831. What momentum has a hand-car weighing 300 lb. moving at the rate of 15 mi. an hour?

832. Find the momentum of a freely falling mass of 3 lb. after falling 256 ft.

833. Find the momentum of a freely falling mass of 2 kg. after falling 3 sec.

834. Which has the greater momentum, a cannon ball weighing 50 lb. moving at the rate of 2000 ft. per second, or a freight car weighing 10 T. moving at the rate of 3 mi. an hour?

835. If one body has five times the mass of another, how must the forces compare to give them (*a*) equal momenta? (*b*) equal acceleration?

836. Two boys collide in a football game with equal momenta. One weighs 220 lb. and had a velocity of 10 ft. per second. What was the velocity of the other boy if his weight is 130 lb.?

837. A rowboat weighing 200 lb. is pulled up to a tugboat weighing 5 T. and 20 ft. away, by means of a rope connecting them. (*a*) Disregarding the resistance of the water, how will their momenta compare at a given instant? (*b*) How much of the distance between them will the tugboat move?

838. A 4-oz. bullet is shot from an 18-lb. rifle with a velocity of 1200 ft. per second. With what velocity will the rifle start in the opposite direction?

839. A rifle weighing 6 kg. discharges a 9-g. bullet with

a velocity of 450 m. per second. With what velocity does the rifle start back against the shoulder?

840. A bullet weighing 10 g. and moving horizontally at the rate of 350 m. per second, strikes and becomes embedded in a suspended block of wood weighing 990 g. What is the velocity of the block after collision?

841. The 2-oz. bullet from a rifle that is being tested, strikes and lodges in a suspended block of wood weighing 19.875 lb. The block immediately moves on with a velocity of 10 ft. per second. What is the velocity of the bullet?

842. An inelastic mass of 10 lb. moving with a velocity of 20 ft. per second, strikes squarely another inelastic mass of 4 lb. which is at rest. Find their common velocity after collision.

843. An elastic ball weighing 2 lb. and moving with a velocity of 15 ft. per second, strikes squarely another elastic ball weighing 3 lb., which is at rest. After collision the smaller ball rebounds with a velocity of 3 ft. per second. What velocity has the large one after collision?

844. An ivory ball at rest, and weighing 30 g., is struck squarely by another ivory ball weighing 200 g., and moving with a velocity of 9 cm. per second. After collision, the smaller ball moves on with a velocity of 15.65 cm. per second. Find (*a*) the velocity of the large ball, and (*b*) its direction.

845. An elastic ball weighing 40 g., and moving at the rate of 30 cm. per second, overtakes another similar ball weighing 60 g. and moving at the rate of 15 cm. per second. After collision the larger one continues in the same direction with a velocity of 27 cm. per second. Find the direction and velocity of the smaller one.

ENERGY

846. What is the potential energy of a half-ton weight if it rests at a height of 13 ft. above the ground?

847. What is the potential energy of a 20-lb. clock weight when wound up, if it can descend 30 in. in running down?

848. (*a*) To what height must the 200-lb. ram of a pile driver (Fig. 12) be raised that it may have a potential energy of 3 ft.-T.? (*b*) If allowed to fall to the ground, with what velocity will it strike?

849. How high will 1800 ft.-lb. of energy raise 80 lb.?

850. What must be the weight of the head of a blacksmith's hammer if, when raised to a height of 3 ft., it has a potential energy of 13.5 ft.-lb.?

851. The center of gravity of the water in a supply tank is 90 ft. above the water motor it supplies. How many cubic feet of water are there in the tank if its total energy is 300 ft.-T.?

852. (*a*) A kilogram weight has what potential energy if placed upon a shelf 430 cm. above the floor? (*b*) If this weight falls from the shelf, with what kinetic energy will it strike the floor?

853. A stone weighing 30 lb. falls from a height of 144 ft. With what kinetic energy does it strike the ground?

854. If the stone in problem 853 had fallen until it acquired a velocity of 144 ft. per second, (*a*) what kinetic energy would it have had at that moment? (*b*) how far would it have fallen?

855. A 40-kg. bag of sand falls from a construction platform 30 m. above the ground. At the instant it strikes, (*a*) what is its velocity? (*b*) what is its energy? (*c*) what is its momentum?

856. A bucket of water weighing 60 lb. breaks away and falls down a deep well. At the end of 2.5 sec., how great is (*a*) its energy? (*b*) its velocity? (*c*) its momentum?

857. A river flows at the rate of 3 mi. an hour. What is its energy per cubic foot of water?

858. A bullet weighing 2 oz. is shot vertically into the air with a velocity of 1200 ft. per second. How much and what kind of energy does it have (*a*) when it leaves the gun? (*b*) 10 sec. later? (*c*) when it reaches the turning point?

859. An arrow weighing 60 g. is shot vertically upward, and returns to the same place in 8 sec. How much and what kind of energy does it have (*a*) when it leaves the bow? (*b*) 50 m. from the ground, going up? (*c*) 50 m. from the ground, coming down?

860. The charge of powder in a cannon gives the 20-lb. projectile an energy of 625 ft.-T. What is the velocity of the projectile at that moment?

861. A bowling ball rolling with a velocity of 10 ft. per second strikes a ninepin with an energy of 8 ft.-lb. What must be the mass of the ball?

862. What must be the mass of a freely falling body if after falling for 5 sec. it strikes with an energy of 1 ft.-T.?

863. A car weighing 2 T. is moving at the rate of 6 ft. per second. (*a*) How great is its energy? (*b*) How great is its momentum?

864. Compare (*a*) the momenta, and (*b*) the energy, of a 50-lb. cannon ball rolling at the rate of 5 ft. per second and a 1-oz. rifle bullet moving at the rate of 1600 ft. per second.

865. If a 2-oz. bullet moving at the rate of 1000 ft. per second will penetrate 1 in. into a pine block, how far would

it penetrate (*a*) if its velocity were 2000 ft. per second? (*b*) if its mass were 4 oz. and its velocity 1000 ft. per second?

866. A train weighing 200 T. and moving at the rate of 15 mi. an hour can be stopped within 40 ft. In how many feet could this train be stopped by the same brake power, (*a*) if its velocity were 45 mi. per hour? (*b*) if its velocity were 60 mi. per hour and its weight were 300 T.?

867. A car running at the rate of 8 mi. per hour can be stopped in its own length. How would its momentum and the distance to stop be changed if its speed were 30 mi. per hour?

ABSOLUTE UNITS

868. How great a force in dynes is needed to give a mass of 1 g. an acceleration of 10 cm. per second per second?

869. How many dynes are needed to give a mass of 1 g. an acceleration of 980 cm. per second per second?

870. What force in dynes is required to give a mass of 80 g. an acceleration of 980 cm. per second per second?

871. A mass of 500 g. acquires a velocity of 80 cm. per second in 5 sec. Find the force acting upon it, assuming it to be constant.

872. A wagon weighing 1000 kg. is acted upon by a constant force that gives it a velocity of 2 m. per second in 4 sec. Find the force.

873. When a force of 50 dynes acts upon a mass of 10 g., what acceleration does it give to the mass?

874. (*a*) How great an acceleration would a force of 1000 dynes give to a mass of 2000 g.? (*b*) If this force acted for 4 sec., what velocity would it give the body?

875. A car which has a mass of 10,000 kg. is moved from rest by a constant force of 200,000,000 dynes. Find (*a*) the

acceleration produced; (*b*) the velocity at the end of one minute; (*c*) the distance covered in 1.5 min.

876. (*a*) If a force of 30 dynes acts upon a mass of 5 g., how great an acceleration will it produce? (*b*) If this force is increased to 90 dynes, how great does the acceleration become? (*c*) If the force remains as it was at first, 30 dynes, and the mass is increased to 15 g., how great does the acceleration become?

877. A force of 5000 dynes acting upon a body at rest gives it a velocity of 100 cm. per second in 4 sec. Find the mass of the body.

878. A motor boat is moving at the rate of 4 m. per second when the power is shut off, and the resistance of air and water brings the boat to a stop in 4 min. Assuming this resistance to have a constant value of 5,000,000 dynes, find the mass of the boat.

879. How great a velocity will a force of 980 dynes give to a mass of 1 g. in 4 sec.?

880. How great a velocity will a force of 3 dynes give to a mass of 10 g. in 2 sec.?

881. What is the value of the force that would give a mass of 20 g. the same velocity at the end of 5 sec. that a force of 980 dynes gives to a mass of 1 g. in 5 sec.?

882. For how long a time must a force of 1000 dynes act upon a body to give it a velocity of 200 cm. per second, if the mass of this body is (*a*) 5 g.? (*b*) 10 kg.?

883. What is the force that in 5 min. would produce a velocity of 100 m. per minute on a mass of 10 kg.?

884. If a constant force acting upon a 20-g. mass for 5 sec. produces a velocity of 500 cm. per second, what velocity would this force produce if it acted for 20 sec. upon a 10-g. mass?

885. A force of 500 dynes acting upon a given mass for 5 sec. produces a velocity of 100 cm. per second. How great a force would be needed to produce a velocity of 200 cm. per second when acting on this mass for 20 sec.?

886. A certain mass has a momentum of 1200, in absolute units. (*a*) If the force used was 400 dynes, for how long a time did it act? (*b*) If the time required was 10 sec., how great was the force?

887. Find the energy in ergs, of a mass of 80 g. moving with a velocity of 200 cm. per second.

888. Find the number of ergs of energy possessed by a 40-g. rifle bullet moving at the rate of 50,000 cm. per second.

889. A bowling ball moving at the rate of 500 cm. per second possesses 125,000,000 ergs of energy. Find the mass of the ball.

890. What must be the mass of a baseball if, when it leaves the pitcher's hand, it is going at the rate of 5000 cm. per second and has 1,875,000,000 ergs of energy?

891. If the energy of a 100-g. bullet is 25×10^9 ergs, find its velocity.

892. If a moving rifle bullet has an energy of 54×10^9 ergs, what force would be required to stop it in (*a*) 10 m.? (*b*) 1 m.? (*c*) 1 cm.? (*d*) 1 mm.?

893. If a moving rifle bullet has an energy of 2×10^{10} ergs, through what distance must the following forces act to stop it: (*a*) 1 g.? (*b*) 2 g.? (*c*) 10^6 g.?

894. A 150-g. baseball leaves the bat with a velocity of 3000 cm. per second. (*a*) How much energy does it possess? (*b*) If it is caught immediately by the short-stop, who moves his hands back 30 cm. in stopping it, what force does he exert?

895. A barrel of a rifle is 70 cm. long; and the force of powder sends the 40-g. bullet out with a muzzle velocity of 50,000 cm. per second. Find (*a*) the energy of the bullet, and (*b*) the average force of the powder. (*c*) If the bullet is at once stopped by penetrating 5 cm. into a plank, what average resistance does the plank offer?

896. (*a*) How many kilogram-meters of energy does a 2-kg. mass possess when it is moving at the rate of 0.5 m. per second? (*b*) how many gram-centimeters? (*c*) how many ergs?

897. A stone, the mass of which is 6 kg., falls at a place where $g = 978$. What kinetic energy will it possess at the end of 10 sec., expressed (*a*) in gravitation units? (*b*) in absolute units?

MECHANICS MISCELLANY

898. Demonstrate the law of Archimedes. Mention any use that can be made of the law. [Sheffield.]

899. A train, starting with uniform acceleration, moves 880 ft. the first minute. In what time will it reach its maximum velocity of 30 mi. an hour, and how far will it have traveled? [Dartmouth.]

900. Draw a vertical line, and from its lower end draw a straight line obliquely upward. Between these two lines, and touching each of them, draw a circle. Let this sketch represent a ball resting between two smooth planes, one of which is a vertical wall.

(*a*) Draw lines to show the directions of the forces acting on the ball.

(*b*) Giving any convenient length to the line representing the force of gravity, show how to find the magnitude of each of the other forces. [Harvard.]

901. A mass of 500 g. has its velocity uniformly changed from 100 cm. per second, to 1000 cm. per second in 20 sec. What is the value of the force, and how much work does it do? [Sheffield.]

902. A boat is driven by steam power at the rate of 8 mi. per hour due west. The current would carry it north at the rate of 4 mi. per hour, and the wind alone would cause a velocity of 2 mi. per hour due east. How far would the boat move in 30 min., and in what direction? [Cornell.]

903. A vessel of 1000 cc. capacity contains air at atmospheric pressure. A pump of 200 cc. capacity is now applied to force air from the free atmosphere into this vessel. If the barometric pressure at the time is 76 cm. of mercury, how great is the pressure in the vessel after 10 full strokes of the pump? [Harvard.]

904. Over two pulleys is stretched a horizontal cord to the ends of which equal weights of 1 kg. each are attached. To the middle of the cord another 1-kg. weight is hung. In what position will the system come to rest? Demonstrate by the parallelogram of forces. [Cornell.]

905. Name and define the C.G.S. units of force and work. The pitch of the screw of a jackscrew is 2 cm. and the lever is 3 m. long. Neglecting friction, how much can a man lift with this screw if he exerts a pull of 50 kilos on the end of the lever? [Dartmouth.]

906. A mass of $\frac{1}{10}$ of a pound attached to the rim of a wheel 4 ft. in diameter and revolving with it breaks away when the wheel is turning 40 times a minute. What energy does the mass carry with it? [Sheffield.]

907. A piece of metal of density 8 having a volume of 5 cc., and a piece of wood of density 0.6 having a volume of 150 cc., are fastened together and placed in water. How

many cubic centimeters of the combination will remain above the surface? [Harvard.]

908. A ball of putty weighing 5 gm., moving with a velocity of 8 cm. per second, strikes a similar ball of the same weight, which is at rest, and the two move on together after the collision.

(*a*) How great is the velocity after the collision?

(*b*) How great is the total kinetic energy of the balls before the collision?

(*c*) How great is the total kinetic energy of the two balls after the collision?

(*d*) What has become of the kinetic energy that has disappeared? [Harvard.]

909. State Newton's three laws of motion, and illustrate each by an example from nature. [Dartmouth.]

910. A uniform bar 200 cm. long, weighing 1 kg., bears at 20 cm. from one end a weight of 2 kg.; at 180 cm. from the same end it rests on a narrow fulcrum; at 190 cm. from the same end it presses upward against a beam.

How great is the pressure against the beam? [Harvard.]

911. A gun whose mass is 120 T. fires a ball whose mass is 800 lb. with a velocity of 2000 ft. per second. What is the velocity of recoil of the gun?

A force of 1000 dynes is applied for $\frac{1}{10}$ sec. to a mass of 5 g. What is the velocity produced? [Princeton.]

912. Define: mass, weight, density, force, moment of force, velocity, acceleration. [Dartmouth.]

913. A block of wood, the density of which is 0.6 and the volume of which is 90 cc., is gently lowered into a vessel filled to the point of overflowing with a liquid of density 0.9. How many cubic centimeters of the liquid will the block cause to overflow? [Harvard.]

914. How can you prove experimentally that "a body immersed in a fluid loses in weight an amount equal to the weight of the fluid displaced"?

Make a diagram and explain the working of the ordinary suction pump, and state what limits the height to which it can lift water. [Princeton.]

915. From a vessel containing air at atmospheric pressure, 76 cm. barometric pressure, 2 tubes lead downward,—one into a cup of water and the other into a cup of mercury, density 13.6. An air pump applied to the vessel at the top takes out $\frac{1}{10}$ of the air. How does the mercury now stand in its tube? How high does the water now stand in its tube? [Harvard.]

916. A man can row 4 mi. an hour in still water. He starts to row straight across a stream 4 mi. wide, but lands 3 mi. below the starting point. At what rate is the river flowing? [Dartmouth.]

917. A body whose weight is 300 lb. is raised in an elevator 70 ft. How much is its potential energy increased? In what units is your result expressed?

What must be the horse power of the motor which can raise the weight the 70 ft. in 5 sec.? [Princeton.]

918. A mass of iron, density 7.5, is placed in a vessel containing mercury, density 13.6. Determine the volume of iron submerged. [Cornell.]

919. A case of shoes 50 × 20 × 12 in. weighs 85 lb. (*a*) If it is lying on its 50 × 20 face, how much work is done in ending it up on its 12 × 20 face? (*b*) Will the force required at the start increase or diminish as the case approaches its upright position? Why?

920. (*a*) If a rifle bullet were shot directly upward with a velocity of 1000 ft. per second, how far would it rise if in a vacuum?

(*b*) If the bullet weighs 1 oz., how great will be the potential energy at the greatest height? (Name the unit of energy.) [Harvard.]

921. State Newton's law of universal attraction. Why is the value of "g" less at the equator than at the poles?

What is the relation connecting the weight of a body with its mass? [Princeton.]

922. State Archimedes' principle, and show how it may be used to measure the density of a solid that does not float in water. [Dartmouth.]

923. A wooden block of density 0.6, 15 cm. long, 10 cm. wide, and 8 cm. thick, carries on its top 20 cc. of metal, and thus loaded the block floats in water with its top 2 cm. above the surface.

(*a*) How many grams does the metal weigh?

(*b*) How great is the specific gravity of the metal? [Harvard.]

924. A piece of metal of density 8, having a volume of 25 cc., and a piece of wood of density 0.6, having a volume of 100 cc., are fastened together and placed in water. How much will the combination weigh in this position? [Harvard.]

925. A body whose mass is 2 g. is acted on by a constant force of 2350 dynes. Assuming that it starts from rest, what will be its velocity at the end of 3 sec., how far will it have moved, and what work will have been done upon it? [Sheffield.]

926. How is the time of vibration of a simple pendulum affected by (1) a change in the length of suspension? (2) a change in the mass of the bob? (3) a change in the amplitude of vibration? (4) a change in the acceleration of gravity? How may the last be changed? [Dartmouth.]

927. Show by a diagram how to rig a pair of double pulleys so that their mechanical advantage shall be 5.

The pressure in a mass of gas is 20 lb. per square inch. How will the volume be affected if the pressure is raised to 90 lb. per square inch? [Princeton.]

928. A bullet weighing 5 g., moving with a velocity of 30,000 cm. per second, lodges in a free block at rest. The block weighs 1000 g. What velocity does it acquire from the bullet? [Harvard.]

929. The height of Niagara Falls is 53 m. Calculate the velocity acquired by the water in its fall. [Sheffield.]

930. Make a drawing and describe the action of an hydraulic press. What is the law regarding the transmission of pressure in a fluid? [Dartmouth.]

931. A body weighing 60 lb. is moving down an incline, the length of which is 10 ft., the height 8 ft., and the horizontal base 6 ft. (*a*) How great a force parallel to the incline is required to keep the velocity from increasing, if there is no friction? (*b*) How great a force, besides friction, parallel to the incline, is required to keep the velocity from increasing, if the coefficient of friction is 0.2, the pressure of the body against the incline being 36 lb. ? [Harvard.]

932. Explain fully the physical ideas conveyed by the terms: gram, acceleration, moment of a force, dyne, and erg. [Sheffield.]

933. In an hydraulic press the area of the face of the press piston is 10 sq. ft., while that of the face of the pump piston is 0.02 sq. ft. The pump is worked by a lever handle, the force being applied 50 in. from the fulcrum and the pump piston being attached 2 in. from the fulcrum. How great a force must be applied to the handle to produce a total pressure of 10,000 lb. on the face of the press piston?

934. A rectangular block weighing 900 g. floats in water. The base of the block is 20 cm. long and 15 cm. wide. How far is this base below the surface of the water? [Harvard.]

935. A bicycle rider starts from the crest of a hill and coasts down it, along a level road and part way up another hill. Describe the transformation of energy which takes place. The *mass* of rider and wheel together is 100 kg. At the bottom of the hill his velocity is 10 m. per second. Compute the kinetic energy. [Cornell.]

936. A meter stick, carrying two masses of 40 and 60 g. at points 10 and 90 cm. from the end, is suspended by a thread so that the stick is horizontal. Neglecting the weight of the stick, find the position of the thread. [Dartmouth.]

937. The mass of a pile-driver hammer is 300 kg. When it is allowed to fall through a distance of 7 m., it drives the pile 40 cm. What is the average force exerted on the pile? [Sheffield.]

938. In the use of any machine, in what is there a saving, in work, in force, or in speed?

What is the efficiency of a machine? The mechanical advantage?

In the case of pulleys, how is the mechanical advantage related to the number of cords? [Princeton.]

939. The law for the breaking-strength of beams supported at the ends and loaded in the middle is

$$\text{strength} \propto \frac{W \times T^2}{L},$$

where W = width, T = thickness, and L = length.

If a beam 20 ft. long, 6 in. wide, and 4 in. thick will break under a load of 2000 lb., how great a load would break a beam of like material 10 ft. long, 3 in. wide, and 2 in. thick? [Harvard.]

940. If a body starting from rest moves over 30 ft. in 3 sec. under a constant acceleration, how far will it move in the fifth second? [Dartmouth.]

941. A rectangular block bearing on its top a load of 800 g. floats in water, with its base, which is 30 cm. long and 20 cm. wide, 4 cm. beneath the surface. How much does the block weigh? [Harvard.]

942. If 3560 ft.-lb. of work are done in propelling a bicycle a mile, what is the average force at the tread of the wheel, exerted by the rider? [Sheffield.]

943. What is inertia? Describe any experiment which illustrates the effect of inertia.

What is the center of mass, or center of gravity, of a body? How would you find the center of mass of a potato? [Princeton.]

944. A bell-shaped vessel of 50 cc. capacity, filled with air at atmospheric pressure when the barometer reads 75 cm., is lowered, open end downward, in mercury till the depth from the general surface of the mercury to the mercury level in the lowered vessel is 100 cm. How many cubic centimeters does the air in the vessel now occupy? [Harvard.]

945. A body slides down a smooth inclined plane in 16 sec., acquiring a velocity of 600 cm. per second. Find the acceleration and the length of the plane. [Sheffield.]

946. What determines the period of vibration of a simple pendulum? Does the period vary from day to day? Does the period depend at all on the locality where it vibrates? Explain. [Cornell.]

947. A mass of 5 g. starting from rest has an acceleration of 10 cm. per second per second. Find (1) the force acting

on it in absolute units, (2) the distance the body goes in 1 min. [Dartmouth.]

948. Prove, using a diagram, the formula $P : W :: H : L$, where

L = the length of the incline,

H = the height of the incline,

W = the weight,

P = the force, parallel to the incline, needed to keep the weight from sliding down, there being no friction. [Harvard.]

949. Resolve a force of 100 units into two components at a right angle to one another, one of which shall have a value of 50 units. What will be the value of the other?

Show how to find the resultant of any five forces meeting at a point and making any angles with one another. [Princeton.]

HEAT

THERMOMETRY

950. During a thunderstorm the temperature falls 18° F. How many Centigrade degrees would this be?

951. How many Fahrenheit degrees would correspond to a change of 30° C.?

952. Change to Fahrenheit reading (*a*) 40° C.; (*b*) 15° C.; (*c*) 0° C.; (*d*) − 10° C.; (*e*) − 40° C.

953. Reduce to Centigrade reading (*a*) 185° F.; (*b*) 70° F.; (*c*) 32° F.; (*d*) 0° F.; (*e*) − 130° F.

954. The absolute zero is − 273° C. What is this on the Fahrenheit scale?

955. The freezing and boiling points of mercury are − 39° C. and 357° C. respectively. What are these points on the Fahrenheit scale?

956. Air liquefies at − 182° C. Express this temperature on the Fahrenheit scale.

957. The liquefying point (boiling point) of hydrogen at normal pressure is − 422° F., and the solidifying point (melting point) is − 431° F. Express these temperatures as Centigrade degrees.

958. What is the Centigrade boiling point of water when the barometer stands at 77.2 cm.?

959. At what temperature Centigrade will water boil when the barometric pressure is 74.2 cm.?

960. Find the Fahrenheit boiling point of water when the barometer reads 775 mm.

961. (*a*) How great in centimeters of mercury would the pressure have to be in a steam boiler to raise the boiling point to 102° C.? Translate this pressure (*b*) into inches of mercury; (*c*) into pounds per square inch.

962. When water in an open dish boils at 209° F., what would be the reading of an accurate barometer placed near by?

963. What is the boiling-point error of a thermometer that reads 99.8° C. in unconfined steam, when the barometer stands at 76.9 cm.?

964. Find the boiling-point error of a thermometer placed in free steam, if it reads 100.3° C. when the barometer reads 75 cm.

965. Find approximately the normal boiling point at Denver, altitude about 5400 ft.

966. How hot, approximately, is boiling water on the top of Mt. Washington, 6300 ft. above sea level?

967. What is the approximate height of a mountain, if water at its summit boils at 95° C.?

EXPANSION OF SOLIDS AND LIQUIDS

968. The coefficient of linear expansion of aluminum is 0.000023. How much would a piece a foot long expand during a rise (*a*) of 5° C.? (*b*) of 5° F.? (*c*) How much would a mile of it expand during a rise of 10° C.?

969. How much will an iron telegraph wire 100 yd. long contract during a cold night, if the temperature falls 20° C.? K = 0.000012.

970. An iron steam pipe (K = 0.000012) is 40 ft. long when cold at 10° C. (*a*) What allowance must be made for

its expansion, if it is to carry steam at 120° C.? (*b*) What will its length be at 120° C.?

971. A copper telephone wire is 500 ft. long at 20° C. What will be its length (*a*) on a summer day when the temperature is 38° C.? (*b*) on a winter day when the temperature is − 20° C.?

972. A lead hot-water pipe is 10 ft. long when put in place at 15° C. How many inches long will it be when water at 203° F. is passing through it?

973. A platinum meter rod is correct at 0° C. What will be its length at 86° F.?

974. The steel pendulum of a clock is 39.1 in. long at 20° C. If the sun shines on the pendulum and warms it up to 35° C., what will its length become?

975. A rectangular steel boiler plate is 100 × 60 cm. in area when riveted into position at 15° C. What does its area become at a temperature of 175° C.?

976. A metal rod 8 ft. long becomes 0.18 in. longer when heated 80° C. (*a*) What is its coefficient of linear expansion? (*b*) What metal may this rod be made of?

977. A brass pipe 20 ft. long at 0° C. becomes 20 ft. 0.55 in. long at 120° C. Find the coefficient of linear expansion for brass.

978. Find the original length of a wrought iron bar that becomes 2 cm. longer when heated from 10° to 310° C.

979. How long must a steel boiler tube have been at 10° C., if it increases in length 0.6 in. when subjected to a temperature of 250° C.?

980. A steel bridge girder 50 ft. long expands 0.2 in. during a certain rise in temperature. What is this rise?

981. A steel piano wire 140 cm. long at 15° C. becomes 141.2 cm. long when a current of electricity is passed through it. How hot does it become?

982. The distance between two marks on a copper bar is found to be 110.20 cm. on a day when the temperature is 60° C. On another day the distance is found to be 110.12. Find the temperature on this second day.

983. The brass rod of a linear coefficient of expansion apparatus is 50 cm. long. The arms of the multiplying lever are 42 cm. and 1.4 cm. in length. As the temperature rises from 20° C. to 100° C., the pointer moves 2.4 cm. up the scale. Find the coefficient for brass.

984. From the following experimental data find the linear coefficient of expansion of iron:

Length of rod before heating	= 66 cm.
Temperature of rod before heating	= 19° C.
Barometer	= 73.3 cm.
Length of long arm of lever	= 45.0 cm.
Length of short arm of lever	= 1.8 cm.
Scale reading before heating	= 2.1 cm.
Scale reading after heating	= 3.6 cm.

985. The volume of a glass ball is 2000 cc. at 0° C. What would be its volume at 70° C.?

986. If 500 cc. of mercury at 0° C. is heated to 10° C., what will its volume become?

987. The true reading of a barometer should be taken at 0° C. If the reading at room temperature of 22° C. is 760 mm., what is the corrected reading? Neglect the expansion of the scale.

EXPANSION OF GASES

988. Change to the absolute Centigrade scale: (*a*) 0° C.; (*b*) 100° C.; (*c*) −40° C.; (*d*) −273° C.; (*e*) 95° F.

989. Reduce to the Centigrade scale: (*a*) 50° Abs. (*b*) 300° Abs.; (*c*) 350° Abs.; (*d*) 350° F.

990. Five hundred cubic centimeters of gas at 200° Abs. is heated to 600° Abs., with no change of pressure. What does the volume become?

991. If 500 cc. of gas under a pressure of 15 lb. per square inch at 200° Abs. is heated to 600° Abs., what must the pressure become to keep the volume unchanged?

992. A quantity of gas occupies 800 cc. when the temperature is 50° C.; what will be its volume if the temperature is (*a*) increased to 150° C.? (*b*) decreased to 0° C.?

993. The storage tank at a gas works contains 50,000 cu. ft. of gas at a temperature of 10° C. By midday the sun has warmed the gas up to 20° C., and as the gas has expanded, the dome of the tank has risen, keeping the pressure constant. How many cubic feet are now in the tank?

994. A certain mass of gas has a volume of 1200 cc. at a temperature of 20° C. Later its volume has become 1500 cc. No change in pressure has occurred. What, then, must be the new temperature?

995. The volume of a certain mass of gas is 2000 cc. at a temperature of 10° C. and a pressure of 76 cm. Later, its volume has become 1800 cc. (*a*) If no change in pressure has occurred, what must be the new temperature? (*b*) If this change in volume is due entirely to a change in pressure, what is the new pressure?

996. A certain quantity of air at normal pressure and at a temperature of 30° C. is heated to 180° C. What pressure will be required to keep the volume constant?

997. A gas cylinder is filled with gas under a pressure of 90 cm. of mercury at a temperature of − 10° C. If the gas is heated to 300° C., what pressure must the cylinder sustain (*a*) in centimeters of mercury? (*b*) in pounds per square inch?

998. A gas cylinder has its safety valve set to open at 200-lb. pressure. Hydrogen gas at a temperature of 7° C. is forced into it until the pressure gauge reads 190 lb. The gas gradually absorbs heat from the room and soon the safety valve opens. How warm is the gas when this occurs?

999. The volume of a mass of air at normal pressure and 15° C. is 90 cu. ft. What space will it occupy if the pressure becomes 5 lb. per square inch, and the temperature changes to 300° C.?

1000. A balloon, as it leaves the ground, partly inflated, contains 20,000 cu. ft. of hydrogen gas under normal pressure and at a temperature of 20° C. What will be its volume when the balloon has risen to such a height that the barometer stands at 50 cm. and the thermometer at − 20° C.?

1001. Twenty-five cubic feet of gas under a pressure of 12 lb. per square inch and at a temperature of − 20° C. is compressed to 5 cu. ft. and heated to 100° C. What pressure does it now exert?

1002. Fifty cubic feet of illuminating gas under normal pressure and at a temperature of 50° C. is forced into a storage cylinder of 5 cu. ft. capacity, and cooled to 5° F. What pressure will the gas exert upon the walls of the cylinder?

1003. A cylinder containing a piston is filled with 500 l. of a gas at normal pressure and 20° C. The piston is pushed in,

compressing the gas to 400 l., and held while the temperature is reduced to $-60°$ C. Will the piston now move in or out if let go?

1004. (*a*) If the piston in problem 1003 were drawn slowly out so that the 500 l. of gas at 20° C. became 600 l. at the same temperature, would the gas have to be heated or cooled if the piston is not to move when let go? (*b*) To what temperature?

1005. A toy balloon contains 300 cu. in. of coal gas when the air around it has a pressure of 29 in. and a temperature of 10° C. If the barometer rises to 30 in., how warm must the surrounding air become to make the balloon expand to 310 cu. in.?

1006. An upright cylinder, closed at the bottom and fitted with a piston at the top, is just full of carbonic acid gas at normal pressure and 10° C. The piston is pushed halfway down and held in place by a weight. To what temperature must the gas now be heated to force the piston back to the top of the cylinder?

1007. The following data are taken from a laboratory experiment made with a dry-air tube:

(*a*) Length of air column in ice water = 14.5 cm.
Length of air column in steam = 19.8 cm.
Barometer = 76.5 cm.

The tube lies flat during this part of the experiment. Find the coefficient of cubical expansion of air at constant pressure. (*b*) The air column is kept from expanding, when surrounded by steam, by tilting the tube so that the outer end of the mercury column is 28.2 cm. higher than the inner end. Find the coefficient of pressure increase of air when the volume is kept constant.

SPECIFIC HEAT

1008. How many calories of heat are required to raise the temperature of (*a*) 5 g. of water 10° C.? (*b*) 8 g. of zinc 20° C.?

1009. How many calories of heat are given out (*a*) when 2 kg. of water cools 90° C.? (*b*) when 700 g. of copper cools from 250° to 140° C.?

1010. If 500 g. of water at 0° C. and 500 g. of mercury at 0° C. are each given the same quantity of heat, how hot will the mercury become when the water has been heated 10° C.?

1011. How many grams of hot water at 100° C. must be poured into 3 l. of cold water at 4° C. to warm it to 20° C.?

1012. When 200 g. of hot water at 80° C. is poured into a pail of water at 14° C., the temperature of the mixture becomes 20° C. How many grams of cold water must there have been in the pail at first?

1013. The water in the hot water faucet is at 96° C. If you have drawn 5 pt. of it into the hand basin, how many pints of cold water at 15° C. must you add to bring the temperature to 60° C.?

1014. If 80 g. of water at 100° C. is poured into 80 g. of water at 10° C., what will be the temperature of the mixture?

1015. If 500 g. of water at 90° C. is poured into 100 g. of water at 30° C., what will be the resulting temperature?

1016. When 50 g. of hot lead shot and 40 g. of cold water are poured together, the lead falls 250° C. in temperature, and the water rises 10° C. Find the specific heat of the lead.

1017. One kilogram of copper at 100° C., when plunged into 600 g. of water at 10° C., raises the temperature of the water to 22° C. Find the specific heat of copper.

1018. Find the water equivalent (or thermal capacity) of a brass calorimeter weighing 92 g.

1019. An aluminum cylinder weighing 120 g. is heated to 90° C., then lowered into a brass calorimeter weighing 80 g. and containing 100 g. of water at 0° C. The final temperature is 18° C. Find the specific heat of aluminum.

1020. One hundred fifty grams of chopped brass wire is heated to 95° C. and poured into a copper calorimeter weighing 90 g. and containing 103 g. of water at 5° C. The resulting temperature is 15° C. Find the specific heat of brass.

1021. How many grams of mercury at 98° C. must be poured into 100 g. of water to raise its temperature from 5° C. to 18° C.?

1022. How many grams of lead shot at 200° F. must be used to raise the temperature of 400 g. of water from 40° F. to 90° F.?

1023. A 60-lb. mass of steel is cooled from 1100° F. to 100° F. by plunging it into a tank containing water at 50° F. How many pounds of water must there be in the tank?

1024. How much alcohol at −10° C. must be mixed with 200 g. of chloroform at 30° C., that the final temperature may be 10° C.?

1025. A roll of sheet lead weighing 500 g. is heated to 250° C. and plunged into a liter of water at 4° C. Find the temperature of the mixture.

1026. If a 50-g. lump of silver, left in ice water until it is cooled to 0° C., is dropped into 100 g. of ether at 30° C., what will be the temperature of the mixture?

1027. If 200 g. of chopped iron wire is heated to 90° C. and poured into a brass calorimeter that weighs 100 g. and contains 500 g. of water at 50° F., what will be the temperature of the mixture?

1028. A ball of aluminum weighing 120 g. is heated in a flame and then dropped into 400 g. of water at 20° C. If the temperature of the mixture is 40° C., how hot must the ball have been?

1029. A lump of platinum weighing 100 g. is thoroughly heated in a furnace and then dropped into 400 g. of water at 0° C., raising the temperature of the water to 10° C. (*a*) How hot was the furnace? (*b*) Why was platinum used?

1030. A substance when tested in the laboratory is found to have a specific heat of 0.0936, a specific gravity of 8.41, and a coefficient of linear expansion of 0.0000183. What is the substance probably?

HEAT OF FUSION AND OF VAPORIZATION

1031. (*a*) How many calories of heat will be absorbed by 10 g. of ice at 0° C. in melting? (*b*) How many calories will be given out by 12 g. of water at 0° C. in freezing?

1032. How many calories of heat will be needed to melt 200 g. of ice at 0° C. and heat it to 50° C.?

1033. A farmer puts into his cellar a tub containing 50 kg. of water at 30° C. How much heat will this water give out into the cellar before it is all frozen?

1034. (*a*) How much heat will be needed to melt an iron kilogram weight? (*b*) If its temperature has first to be raised from 20° C., how much heat would be needed to melt it?

1035. How many grams of ice at 0° C. must be mixed with 200 g. of water at 90° C., that the temperature of the mixture may be 40° C.?

1036. How many pounds of ice at 0° C. will be needed to reduce the temperature of 10 lb. of water from 95° C. to 25° C.?

1037. How much water at 100° C. will it take to melt 300 g. of ice at 0° C. and raise its temperature to 30° C.?

1038. If a 500 g. brass weight is heated to 200° C. and placed on a block of ice, how many grams of the ice will be melted if there are no losses?

1039. A copper calorimeter weighing 110 g. contains 300 g. of water at 100° C. How many grams of ice at 0° C. must be dropped in to lower the temperature to 60° C.?

1040. A lump of ice weighing 90 g. is placed in a silver mug that weighs 150 g. and is at 0° C., then some hot water at 70° C. is poured in. The mixture is stirred with a thermometer, which reads 10° C. just after the ice has all melted. How much hot water was used?

1041. If 500 g. of ice at 0° C. and 600 g. of water at 100° C. are mixed, what will be the resulting temperature?

1042. A brass calorimeter weighing 120 g. holds 200 g. of water at 55° C. If 90 g. of ice at 0° C. were put in and allowed to melt, to what temperature would the hot water and calorimeter be lowered?

1043. Two hundred grams of alcohol is poured into a copper calorimeter weighing 90 g. The temperature is taken and found to be 60° C. If 30 g. of ice were dropped in, what would the temperature become?

1044. From the following data calculate the heat of fusion for ice:

Weight of calorimeter (brass)	= 90 g.
Weight of calorimeter and warm water	= 400 g.
Temperature of warm water	= 30° C.
Temperature of water when ice is melted	= 10° C.
Weight of calorimeter and cold water	= 471 g.

1045. A ladleful of molten silver at 950° C. is poured into 400 g. of water at 0° C., raising the temperature of the water to 50° C. How many grams of silver were there in the ladle?

1046. If 200 g. of melted lead at 326° C. is poured into a calorimeter containing 150 g. of water at 5° C., how hot will the water become? The calorimeter is made of brass and weighs 80 g.

1047. A copper calorimeter weighing 120 g. contains 417 g. of ice and 200 g. of water at 0° C. When 100 g. of melted zinc at 415° C. is poured in, the ice melts and the temperature of the mixture becomes 15° C. Find the heat of fusion of zinc.

1048. (*a*) How many calories of heat are required to vaporize 10 g. of water at 100° C.? (*b*) How many calories of heat does 2 g. of steam at 100° C. give out in condensing?

1049. How many calories of heat will it take to heat 1 kg. of water at 10° C. and turn it to steam at 100° C.?

1050. How many calories of heat will 800 g. of steam give up to a radiator, if it enters as steam at 100° C. and leaves as water at 90° C.?

1051. How much heat will be needed to heat 500 g. of alcohol from — 100° C. to its boiling point and then vaporize it?

1052. How much heat will be needed to melt 8 g. of ice at 0° C. and turn it to steam at 100° C.?

1053. If 6 g. of steam at 110° C. is changed to ice at — 10° C., how much heat will be given out? (Look up specific heat of ice and of steam.)

1054. If steam at 100° C. is blown into 200 g. of water at 36° C. and raises its temperature to 86° C., how many grams of steam is condensed?

1055. How many pounds of water at 0° C. would 1 lb. of steam at 100° C. warm to 50° C.?

1056. A radiator made of iron and weighing 100 kg. is heated by steam from 20° C. to 60° C. How many grams of steam at 100° C. must have been used, assuming that no heat has been radiated?

1057. How many grams of ice at −8° C. would 50 g. of steam at 110° C. melt and heat to 30° C., if there were no losses?

1058. How many grams of steam at 266° F. would be required to heat 1 kg. of ice from − 22° F. to 32° F., melt it, and raise its temperature to 122° F.?

1059. If 5 lb. of steam at 120° C. is turned into a 300-lb. radiator (cast iron) at 10° C., how hot will the radiator become if no losses occur?

1060. How much aluminum at 100° C. would be required to heat 60 g. of ether at 30° C. up to its boiling point and vaporize it?

1061. A 90-g. brass calorimeter contains 400 g. of water at 5° C. What will be the temperature of the mixture, if 20 g. of steam at 100° C. is passed into the water?

1062. From the following data, calculate the heat of vaporization for water:

Weight of calorimeter (brass)	= 80 g.
Weight of calorimeter and cold water	= 500 g.
Temperature of cold water	= 2° C.
Temperature of warm water (mixture)	= 42° C.
Weight of calorimeter and mixture	= 528.8 g.

THERMODYNAMICS

1063. How many foot-pounds of energy does it take (*a*) to heat a pound of water 6° C.? (*b*) to melt 2 lb. of ice at 0° C. and turn it to steam at 100° C.? (*c*) to heat 5 lb. of iron 10° C.?

1064. How many foot-pounds of energy does it take (*a*) to heat a pound of water 12° F.? (*b*) to heat a cubic foot of water from 40° F. to 120° F.? (*c*) to heat a 10-lb. lead weight 20° F.?

1065. How many degrees Centigrade would a foot-ton of energy heat (*a*) a pound of water? (*b*) a pound of aluminum?

1066. Through how many feet would a half-ton weight have to fall to generate energy enough to raise the temperature of 5 lb. of water 10° F.?

NOTE. — In the following problems it is assumed, unless otherwise mentioned, that all the kinetic energy is transformed into heat in the moving body itself.

1067. (*a*) If a pound of water fell a distance of 1556 ft., how many degrees F. would its temperature be raised in stopping? (*b*) If 10 lb. of water fell instead of 1 lb., what would be the answer to (*a*)?

1068. From what height must a cubic foot of water fall in order that the energy of impact may raise its temperature (*a*) 3° C.? (*b*) 4° F.?

1069. From what height would a lump of aluminum have to fall that the energy of impact should raise its temperature 3° F.?

1070. A brass weight falls to the ground from a height of 1000 ft. How many degrees warmer does it become, expressed (*a*) in Centigrade? (*b*) in Fahrenheit?

1071. A lead bullet weighing 1 oz. strikes a target with a velocity of 1600 ft. per second. Assuming that 20% of the energy heats the bullet, find its rise in temperature in Centigrade degrees.

1072. (*a*) What is a calorie? Find the equivalent of the calorie (*b*) in foot-pounds; (*c*) in kilogram-meters. (These values are to be used in the next three problems.)

1073. A car weighing 7 T. and moving at the rate of 30 mi. an hour is stopped by application of the brakes. How many calories of heat are produced?

1074. An iron nail weighing 4 oz. and resting on an anvil is struck by a 20-lb. hammer moving at the rate of 30 ft. per second. (*a*) How many calories of heat are produced? (*b*) If all of the heat developed is absorbed by the nail, what is its rise in temperature?

1075. A cast-iron ball weighing 20 kg. strikes the ground from a height of 100 m. (*a*) How many calories of heat are developed? (*b*) If 70 % of this heat remains in the ball, what is its rise in temperature?

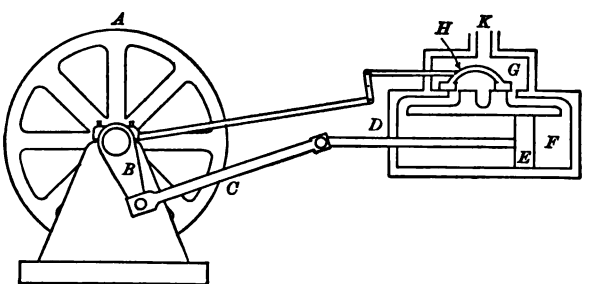

FIG. 33.

1076. The cylinder of a steam engine (Fig. 33) is 150 sq. in. in cross section, and the length of stroke is 2 ft. If the mean effective pressure of the steam is 100 lb. per square

inch, how much work is done (*a*) in a single stroke? (*b*) in 5 complete (double) strokes, *i.e.* in 5 revolutions of the fly wheel?

1077. What is the horse power of the engine in problem 1076, if the number of revolutions per minute is 100?

1078. Find the horse power of a steam engine that has a cylinder 10 in. in diameter and a stroke 18 in. long, if it makes 200 revolutions per minute under an average pressure of 40 lb. per square inch.

1079. A reciprocating steam engine (Fig. 33) works under a mean pressure of 90 lb. per square inch. The cylinder, *F*, is 14 in. in diameter and the length of the crank, *B*, to which the connecting rod, *C*, is attached, is 7.5 in. When the fly wheel, *A*, makes 80 revolutions per minute, at what horse power is the engine working?

1080. A locomotive with cylinders 20 in. in diameter, a stroke of 24 in., and driving wheels 72 in. in diameter, is designed to run at a speed of 60 mi. an hour under a mean effective steam pressure of 50 lb. Under these conditions, what is the horse power of the locomotive? Do not forget that there is a cylinder on each side of the locomotive.

1081. What should be the mean effective pressure to cause a 10 h.p. hoisting engine to make 300 revolutions per minute? The area of the piston is 50 sq. in. and the stroke is 1 ft.

1082. What should be the diameter of the cylinder of a 7 h.p. steam engine, if it is to make 200 revolutions per minute under a mean effective pressure of 20 lb. per square inch? The length of stroke is 12 in.

HEAT MISCELLANY

1083. State the law which connects the volume and pressure of a gas at constant temperature. From what do we get our idea of absolute temperature? What is the absolute zero? [Dartmouth.]

1084. Draw a simple diagram representing the plan of some form of boiler used to supply steam for an engine or for heating a building. Show the grate, the hot-air pipes, the water level, the water gauge, the steam gauge, and the safety valve. [Harvard.]

1085. Mention four facts which indicate that heat is a form of energy.

How can you explain the increase of pressure of a gas produced by a rise of temperature?

What is Joule's equivalent? [Princeton.]

1086. How may a block of ice be used as a calorimeter? [Sheffield.]

1087. Express 72° C. in F. 72° F. in C. 27° C. in absolute.

Seventy grams of an oil, at 70° C., whose specific heat is .7, are poured into 400 g. of water at 23°. What will be the temperature of the mixture? [Princeton.]

1088. If the mechanical equivalent of heat on the basis of pounds, feet, and degrees Fahrenheit is 778, how far must a body, the specific heat of which is 0.1, fall in order that the heat generated may be enough to raise the temperature of the body 5° F.? [Harvard.]

1089. If heat be applied uniformly to ice initially at − 10° C., until the temperature of the substance has risen to 15° C., what different effects will be noted, and what relative times will have been occupied in each process? [Sheffield.]

1090. If the coefficient of *cubical expansion* of iron is 0.000033, at what temperature will an iron bar be 1 m. long, if it is 1.0001 m. at 20° C.? [Harvard.]

1091. The volume of a certain amount of gas is 1500 cc. when its temperature is 7° C. If the pressure is kept constant, what will the volume become when the gas is heated to 287° C.? When the gas is cooled to −133° C.? [Princeton.]

1092. Draw a diagram showing how a house is heated by a hot-air furnace; represent the furnace (as simply as possible), the cold-air duct, and the hot-air pipes. Explain your diagram. [Harvard.]

1093. What is heat? State some of your reasons for your answer to the above question.

Show how you can change the expression for a given temperature from the Centigrade to the Fahrenheit scale. [Princeton.]

1094. If 1 kg. of coal yields enough heat to raise 7000 kg. of water 1° C., how much coal would be required to turn 10,000 kg. of snow taken at −10° C. into water at 10° C.? (Take the specific heat of snow as 0.5 and the latent heat of melting as 80.) [Harvard.]

1095. Three hundred cubic centimeters of a gas are under a pressure of 760 mm. of mercury when at 27° C. What will the pressure become if the volume is kept constant but the temperature is raised to 327° C.? The temperature pressure coefficient is .00336.

Why can you "see your breath" on a cold day? [Princeton.]

1096. Show by means of a diagram the circulation of steam in the cylinder of a very simple steam engine. The diagram should show a cut through the cylinder, piston, and sliding valve, with arrows to indicate the course of the steam and the direction of motion of the piston at the instant. [Harvard.]

1097. Name and define the C. G. S. unit of heat. Define latent heat and specific heat. Outline a method of measuring the specific heat of a substance. [Dartmouth.]

1098. A certain quantity of air has a volume of 800 cc. at 50° C. under a pressure of 76 cm. of mercury. What would its volume be at a temperature of 150° C. under a pressure of 152 cm. of mercury? [Harvard.]

1099. (1) While a train is running 45 mi. an hour the steam is shut off and the brakes applied so as to produce a retardation of 3 ft. per second in a second. In what distance will the train stop? (2) If the mass of the train in the preceding example is 200 T., how much heat will be developed? The mechanical equivalent of heat may be taken as 778 ft.-lb. per pound degree Fahrenheit. [Sheffield.]

1100. Water falling to the ground from a height of 1400 ft. would generate sufficient heat to raise its own temperature 1° C. If 1 lb. of ice were to be melted by mechanical work, how many foot-pounds would be required? [Harvard.]

1101. Thirty grams of water at 80° C. are poured into 80 g. of water at 30° C. What is the resulting temperature?

How do the boiling and freezing points of water vary with pressure? [Princeton.]

1102. Describe any case in which use is made of the unequal expansion of two solid substances with rise of temperature, or any case in which such unequal expansion may do harm. [Harvard.]

1103. Define calorie, latent heat, and specific heat. A piece of copper weighing 100 g. with a specific heat of 0.09 and at a temperature of 50° C. is quickly dropped into a vessel containing water and ice. How much ice will be melted by the heat lost by the copper? [Dartmouth.]

LIGHT

PHOTOMETRY

1104. At a time when a hitching post 4 ft. tall casts a shadow 6 ft. long, a telegraph pole casts one 72 ft. long. How tall is the pole?

1105. A small room is made perfectly dark except for a small hole in the window shutter. The image of a 6-ft. man, standing outdoors 12 ft. from the hole, is produced on the wall of the room 5 ft. from the hole. What is the length of the image?

1106. A closed box, 12 in. square on the base and 10 in. high, has a pin hole in the middle of one of the vertical sides. If the box is used as a camera, how near in front of the pin hole must a boy 5 ft. 5 in. tall stand that his image may be produced on the back wall of the box?

1107. Draw a diagram to show how a total eclipse of the moon is produced. Label the different parts of the shadow.

1108. Draw a diagram to show how a total eclipse of the sun is produced. Label the different parts of the shadow.

1109. The average radius of the earth's orbit is 93,000,000 mi. How long would it take light to pass directly across this orbit?

1110. The nearest star is about 20,000,000,000,000 mi. from the earth. How many years ago did the light by which we see that star to-night leave it?

1111. If a screen 1 ft. square is placed 10 ft. from a lighted candle and broadside to it, what fraction of the light will it intercept?

1112. A card is held flatwise halfway between a lamp and the opposite wall. How will the area of the shadow compare with that of the card?

1113. A lighted lamp stands 144 in. from the nearest wall. If a rectangular card 8 × 10 in. is held face to the lamp and at $\frac{1}{8}$ of the distance from lamp to wall, (*a*) how do the sizes of the shadow and card compare? (*b*) What are the dimensions of the shadow?

1114. If a light is 5 m. from the nearest wall, where must a card 10 cm. square be placed to make a shadow (*a*) 50 cm. square? (*b*) 7500 cm.^{2} in area?

1115. (*a*) A printed page, placed at a distance of 1 ft. from a luminous point and broadside to the light, casts how large a shadow on the wall 3 ft. back of the book? (*b*) If the page were placed against this wall, what part of the original light would it now intercept?

1116. What are the comparative intensities of light on the page of a book at distances of 1 ft., 5 ft., and 10 ft. respectively from the source?

1117. If two screens placed 1 m. and 2 m. respectively from a luminous point receive the same amount of light, how must their areas compare?

1118. Two standard candles are placed one on each side of a screen at distances of 1 m. and 3 m. respectively. (*a*) Compare the intensity of the illumination of the two sides

of the screen. (*b*) That the illumination may be the same on both sides, how many candles should be used on the 3 m. side?

1119. In order that two pictures may be equally illuminated, one by an incandescent lamp 5 ft. away, the other by an arc lamp 50 ft. away, what must be the relative intensities of the two lamps?

1120. Find the candle power of a gas flame if, when placed 11 ft. from a card, it illuminates it as much as a standard candle would at a distance of 1 ft.

1121. What must be the candle power of a lamp if, when placed 6 ft. from a screen, it illuminates it as much as two standard candles would at a distance of 9 in.?

1122. If the page of your book is satisfactorily illuminated when 3 ft. from the light, how bright should the light be made to keep the page illuminated the same when you move it 2 ft. farther away?

1123. At what distance will a 16 c.p. lamp give the same intensity of illumination that a standard candle 70 cm. away does?

1124. In photography, in making a Velox print, artificial light is generally used, and the length of the exposure varies inversely as the intensity of the light falling on the print. If 50 sec. is the proper exposure when the print is 5 ft. from the light, how long should the exposure be (*a*) at a distance of 2.5 ft.? (*b*) at a distance of 15 ft.?

1125. Referring to problem 1124, what would be the correct exposure (*a*) at a distance of 2 ft.? (*b*) at a distance of 6 ft.?

1126. Referring to problem 1124, at what distance would the correct exposure be (*a*) 200 sec.? (*b*) 5 sec.?

NOTE.—The following nine problems refer to the Bunsen (or Rumford) photometer. P_1 and P_2 are the intensities of the two lights expressed in candle power; d_1 and d_2 are their respective distances from the screen:

	P_1	d_1	d_2	P_2
1127.	1	3	12	?
1128.	1	25	75	?
1129.	1	28	72	?
1130.	1	12	88	?
1131.	1	22	78	?
1132.	1	10	?	81
1133.	1	15	?	50
1134.	1	?	70	40
1135.	1	?	40	5

1136. A standard candle and a 4 c.p. incandescent lamp are placed on a meter stick at the 0 and the 100 cm. marks respectively. At what point between them may a card be placed to receive the same illumination from each?

1137. The distance between a standard candle and a 16 c.p. lamp is 10 ft. How far from the candle, perpendicular to the line joining the two lights, should a screen be placed to be equally illuminated on both sides?

1138. The scale on a Bunsen photometer is 100 in. long. If a standard candle is at one end of the scale and a 20 c.p. lamp is at the other, where must the screen be placed to be equally illuminated on both sides?

REFLECTION

1139. A plane mirror is screwed to a wall. Mr. A, standing in front of the mirror, sees the reflection of Mr. C, who is standing also in front of the mirror but farther to the right. (*a*) Where does Mr. C appear to be? (*b*) Show by diagram

the real and the apparent paths of one of the rays of light from Mr. C to Mr. A.

1140. Construct the image of the capital letter Z as seen in a plane mirror.

1141. Draw a large italic capital letter *N*, and construct the image of it as seen in a plane mirror.

1142. A man looking into a plane mirror sees the reflection of some object behind him. Show by a diagram how far to the right and to the left he may move and still see the reflection of the object.

1143. (*a*) If a man walks toward a plane mirror at the rate of 6 ft. a second, how fast does he approach his image? (*b*) If he holds his watch face to the mirror and glances at it, what time will it appear to indicate if the time reading is 4.30?

1144. In order that a man may see a full-length image of himself in a plane mirror placed parallel to him, the mirror must be at least half as tall as the man. Show why this is so.

1145. A plane mirror is screwed to the middle of one wall of a room 12 ft. cube. What must be the dimensions of the mirror that a man with his eyes in the center of the room may see the reflection of the entire opposite wall? Diagram.

1146. (*a*) If a ray of light makes an angle of 30° with a plane mirror, what angle will the reflected ray make with the incident ray? (*b*) If the mirror is turned so that the angle of incidence is increased 1°, what change will this make in the angle between incident ray and reflected ray?

1147. Two plane mirrors, *M* and *N*, are placed facing each other, parallel, and 4 in. apart. A lighted candle is placed between them, 1 in. from *M*. (*a*) Show by diagram

the position and distance of the first and second image in each mirror. (*b*) Complete this diagram to show the apparent and real paths of one ray of light from each image to the eye of an observer.

1148. How many images will be formed in two plane mirrors placed (*a*) at right angles? (*b*) at an angle of 60°? (*c*) at an angle of 10°? (*d*) At what angle must they be placed to form nine images?

1149. Two plane mirrors, *M* and *N*, make an angle of 90° with each other. (*a*) Show by diagram the position and distance of each image of an object that stands 3 in. from *M* and 4 in. from *N*. (*b*) Complete this diagram to show how an observer sees each image.

1150. Two plane mirrors, *CM* and *CN*, make an angle of 45° with each other. Draw a diagram making each mirror about 2 in. long. Place an object, *O*, between them about 1.5 in. from their vertex. (*a*) Find carefully the position of each image. (*b*) With *C* as a center and *CO* as a radius, draw a circle.

1151. The radius of curvature of a concave mirror is 20 cm. What is the focal length?

1152. In a concave mirror, where would the image be formed of an object located (*a*) at infinity? (*b*) just outside the center of curvature? (*c*) at the center of curvature? (*d*) between the center of curvature and the focus? (*e*) at the focus? (*f*) between the focus and the center of the mirror?

1153. Under what conditions is a real image produced (*a*) in a concave mirror? (*b*) in a convex mirror? Under what conditions is a virtual image produced (*c*) in a concave mirror? (*d*) in a convex mirror?

1154. State the conditions under which a magnified image is produced (*a*) in a concave mirror; (*b*) in a convex mirror. In each of these cases state whether the image is real or virtual, erect or inverted.

1155. Find the focal length of a concave mirror, if an object placed 10 cm. before it produces an image (*a*) 30 cm. before the mirror; (*b*) 30 cm. behind the mirror.

1156. Find the focal length of a concave mirror, if an object 30 in. before it produces (*a*) a virtual image 120 in. from the mirror; (*b*) an inverted image 120 in. from the mirror.

1157. Find (*a*) the focal length and (*b*) the radius of curvature of a convex mirror, if an object 40 in. out on the principal axis has its image 10 in. back of the mirror.

1158. A lighted candle is placed 100 cm. before a concave mirror which has a focal length of 10 cm. (*a*) Where will the image be formed? (*b*) Will the image be real or virtual?

1159. The center of curvature of a concave mirror is 50 cm. from the mirror. Ten centimeters inside this point an object is placed. (*a*) Where will the image of it appear? (*b*) Will this image be a magnified or a reduced image?

1160. A pencil 5 in. long is placed 18 in. in front of a concave mirror which has a radius of curvature of 12 in. (*a*) Where will the image be formed? (*b*) How long will the image be?

1161. The focal length of a concave mirror is 15 in. What will be the length of the image of a 6-in. arrow if placed (*a*) 5 in. outside the focus? (*b*) 5 in. inside the focus?

1162. The focal length of a concave spherical mirror is 12 in. Where must a gas flame be placed to produce on a screen an image of the flame magnified 20 diameters?

1163. At what two distances from a concave mirror, the focal length of which is 15 in., can an object be placed to produce an image magnified three diameters?

1164. An arrow 8 in. long is placed before a concave mirror, at a distance equal to three times its focal length. (*a*) Where (in terms of focal length) will the image be formed? (*b*) How long will it be?

1165. An object is placed 30 cm. in front of a convex mirror, the focal length of which is 40 cm. (*a*) Where will the image be? (*b*) Where should the object be placed to produce a real image?

1166. A man stands with his face 60 in. from a convex mirror, the radius of curvature of which is 40 in. (*a*) Is the image larger or smaller, inverted or erect, real or virtual? (*b*) Disregarding distortion, what will be the relative size (width) of the image?

1167. A lighted candle placed twice as far in front of a convex mirror as the focus is behind the mirror, produces an image 4 in. long. How long is the candle?

REFRACTION

1168. Find by construction the index of refraction from air to glass, if the angles of incidence and refraction are 70° and 39° respectively.

1169. Taking the index of refraction, air to water as 4/3, find by construction the angle of incidence, if the angle of refraction is 20°.

1170. Take 3/4 as the index of refraction from water to air, and find by construction the critical angle for water.

1171. The critical angle for light passing from diamond to air is 23° 41′. Find by construction the index of refraction.

1172. The velocity of light in air is approximately 186,000 mi. per second. Taking 1.70 as the index of refraction from air to carbon bisulphide, find the approximate velocity of light through carbon bisulphide.

1173. What is the index of refraction of a liquid in which light travels with a velocity of 136,000 mi. per second?

1174. If you focus a camera (Fig. 34) upon an approaching object, must the ground-glass plate in the camera be moved toward the lens or from the lens as the object comes nearer? Show by diagram.

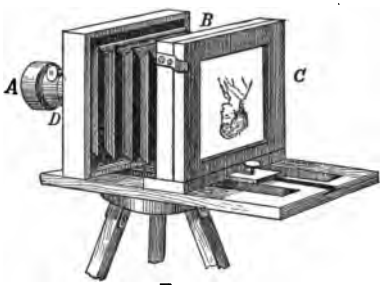

FIG. 34.

1175. Make a diagram to show how a copying camera can make a picture (*a*) smaller than the original; (*b*) the same size as the original; (*c*) larger than the original.

1176. In photographing an object you find that when the object is 6 ft. from the lens, the ground-glass plate in the camera must be just 8 in. from the lens. What is the focal length of the lens?

1177. (*a*) What must be the focal length of a convex lens, if object and image are on opposite sides of the lens and respectively 40 cm. and 10 cm. distant from it? (*b*) Will the image be real or virtual?

1178. What is the focal length of a convex lens if an object 10 cm. distant produces (*a*) a real image 20 cm. from the lens? (*b*) a virtual image 20 cm. from the lens?

1179. A convex lens is used to throw an image of an incandescent lamp upon a card 90 in. distant. When the lens is

placed 10 in. from the card, the image is sharp. Find (*a*) the focal length of the lens, and (*b*) the relative lengths of object and image.

1180. What is the focal length of a convex lens, if an inverted image 10 times as long as the object is thrown on a screen 5 ft. from the lens?

1181. A convex lens of 30-cm. focus is at a fixed distance from a screen. When a gas flame is placed 40 cm. from the lens, the image on the screen is distinct. How far apart are the lens and the screen?

1182. A luminous object placed 70 in. in front of a convex lens of 4-in. focus forms an image on the screen. (*a*) Will this image be erect or inverted? (*b*) Where will it be?

1183. One of the conjugate foci of a convex lens of 15-cm. focus is 90 cm. from the lens. Where is the other one?

1184. The image of a lighted candle is to be thrown by a convex lens of 24-in. focus on to a screen 14 ft. from the lens. (*a*) Where must the candle be held? (*b*) If the candle is 2 in. long, what will be the length of the image?

1185. The focal length of a camera lens is 12 in. (Fig. 34). (*a*) How near the lens must the sensitized plate be in photographing a distant object? (*b*) How near must it be in photographing a man 10 ft. away? (*c*) If the man is 6 ft. tall, how tall a plate must be used?

1186. The image of a building 400 ft. away is 6 in. tall on the ground-glass plate of a camera of 12-in. focal length. How high is the building?

1187. (*a*) If a luminous object is placed 12 cm. from a convex lens, the focal length of which is 10 cm., where will the image be produced? (*b*) If this object is moved 4 cm. nearer the lens, where will the image be?

1188. A hand magnifier of 3-cm. focus is held 2.7 cm. from the object. (*a*) What kind of image will be formed? (*b*) Where will it be formed? (*c*) How much will it be magnified?

1189. If it is desired to have a simple magnifying glass that when held 3 in. from a small insect shall magnify it 6 diameters, what must be the radius of curvature of the lens?

1190. How near an object must a hand magnifier of 1-in. focus be placed to produce a magnification of 8 diameters?

1191. How far from a printed page must a reading glass of 5-in. focus be held to magnify 10 diameters?

1192. An object is placed 8.5 mm. from a double convex lens of 8-mm. focus. (*a*) What kind of image will be formed? (*b*) Where will this image be? (*c*) How much will it be magnified?

1193. The image formed in problem 1192 is viewed through a simple magnifier of 50-mm. focus, so placed that the distance from this image to the magnifier is 42 mm. (*a*) What kind of image will be formed by the magnifier? (*b*) Where will this image be? (*c*) How much will it be magnified?

1194. The combination of lenses mentioned in problems 1192 and 1193 may be considered as forming a compound microscope, in which the 8-mm. lens is the objective and the 50-mm. lens is the eyepiece (Fig. 35). Find the magnifying power of the whole microscope.

1195. The objective, *O*, of a compound microscope (Fig. 35) has a focal length of 4 mm., and the eyepiece, *E*, a focal length of 20 mm. When the object is placed 4.1 mm. from the objective, find (*a*) the position of the real image formed by it; (*b*) the magnifying power of the objective; (*c*) the length of the image if the object is 0.1 mm. long. (*d*) If this image lies 2 mm. inside the focus of the eyepiece,

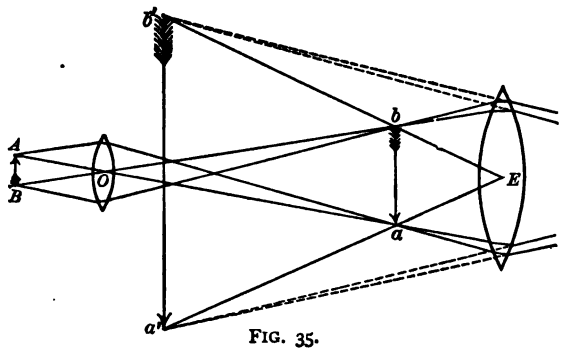

FIG. 35.

where will the virtual image be formed? (*e*) Find the magnifying power of the eyepiece. (*f*) Find the magnifying power of the microscope as a whole. (*g*) Find the length of the final image.

LIGHT MISCELLANY

1196. A real image formed by a concave mirror, the focal length of which is 30 cm., is twice as long as the object. (*a*) How far from the mirror is the object? (*b*) How far from the mirror is the image? [Harvard.]

1197. Make a diagram illustrating the construction and use of some very simple form of "magic" or "projection" lantern. [Harvard.]

1198. The index of refraction of a substance is 2.5. When the angle of incidence is 15°, show by a diagram what the angle of refraction will be. [Princeton.]

1199. State the laws of the reflection of light, and apply them to find the position of the images of an object between two mirrors at right angles. [Dartmouth.]

1200. A simple convex lens of 20-cm. focal length is placed in one end of a box and is used to give an image of a small

object which is 200 cm. distant from the lens. How long must the box be in order that the image may be in focus on the end of the box opposite the lens? [Harvard.]

1201. Give clearly one method of finding accurately the velocity of light. [Dartmouth.]

1202. What sort of eyeglasses should near-sighted or short-sighted persons wear? Illustrate your answer by means of a diagram. [Harvard.]

1203. What sort of eyeglasses should far-sighted persons use, — that is, persons who cannot without glasses see distinctly a near object? Illustrate your answer by means of a diagram. [Harvard.]

1204. Explain dispersion, and show its application in the spectroscope; give the essential parts of a spectroscope; is it a qualitative or a quantitative instrument? [Dartmouth.]

1205. Describe the construction and action of some form of *camera obscura* having no lens. [Harvard.]

1206. In the use of a certain convex lens the object is 10 cm. from the lens and the image is 40 cm. from the lens, both being on the same side of it. How great is the focal length of the lens? [Harvard.]

1207. How has it been proved that the sun contains some at least of the elements which exist in our earth? [Harvard.]

1208. Explain the origin and meaning of the dark lines crossing the spectrum of the sun. Have you ever seen them? [Dartmouth.]

1209. The focal lengths of objective and eyepiece of a compound microscope (Fig. 35) are 18 mm. and 25 mm. respectively. When the object is placed 20 mm. from the objective, the real image is formed 23 mm. from the eyepiece. Find the magnifying power of the microscope.

1210. State the laws of the refraction of light, and apply them to trace the direction of a ray of light through a plate of glass inclined to the incident light. [Dartmouth.]

1211. A horizontal ray of light traveling exactly west strikes a vertical plane mirror at such an angle as to travel exactly north after reflection. If the mirror were turned about a vertical axis through 8° from its present position, the north edge swinging toward the west, what would be the direction of the reflected ray? [Harvard.]

1212. Show how it is possible, by comparing the spectrum of a star with the spectrum of the sun, to tell whether the star is approaching or receding from the earth. [Harvard.]

1213. Show how a single lens is used as a simple microscope or reading glass. Construct carefully the diagram. [Dartmouth.]

1214. The two sides of a paper disk are illuminated equally by a candle flame 50 cm. distant on one side and a gas flame 200 cm. distant on the other side; compare the intensities of the two lights at equal distances from their sources. [Harvard.]

1215. (*a*) Show how a beam of light may be bent at right angles by a glass prism. (*b*) Define *critical angle*, in its optical sense. [Harvard.]

1216. Describe with diagram an astronomical telescope. [Dartmouth.]

1217. Describe the purpose of the lens in a camera. The focal length of a camera lens is 8 inches; a distinct image of a post is formed on the ground glass when it is at a distance of 10 inches from the lens: how far away is the post? Define conjugate foci. [Case.]

1218. (*a*) Define *focal length* of a mirror.

An object is 10 cm. from a mirror, and the image of the object is 30 cm. from the mirror on the same side as the object.

(*b*) Is the mirror concave or convex?

(*c*) What is the focal length of this mirror? [Harvard.]

SOUND

VELOCITY

NOTE. — In the following problems if the temperature is not mentioned, assume it to be 0° C.

1219. When the thermometer is at 0° C., (*a*) how many feet will sound travel in 10 sec.? (*b*) how many miles a minute?

1220. When the temperature is 20° C., (*a*) how many feet away from its source will the sound of a gong be in 2 sec.? (*b*) how many meters?

1221. The report of a rifle is heard 3 sec. after the puff of smoke is seen. If the temperature is 77° F., how far away is the rifle?

1222. Five seconds after a flash of lightning is seen, the clap of thunder is heard. The temperature is 86° F. (*a*) How far away did the discharge occur? (*b*) In determining approximately the distance of lightning, how many miles may be estimated per second of interval between flash and report?

1223. When a factory whistle is blown, how soon will it begin to be heard in a town 3 mi. distant? Temperature 15° C.

1224. If a man sets his watch from the 12 o'clock alarm sounded on the fire bell 1 mi. away, what correction must he make on a day when the temperature is −15° C.?

1225. What is the velocity of sound, expressed in meters per second, in oxygen, the specific gravity of which is 1.1 referred to air? Assume elasticity to be constant.

1226. Find the velocity of sound in meters per second in hydrogen, which has a specific gravity of 0.07 referred to air. Assume elasticity to be constant.

1227. Carbon dioxide has a density 1.52 times as great as air. Compute the velocity of sound in this gas, in meters per second, assuming elasticity to be constant.

1228. A man standing some distance in front of a cliff fires a pistol and hears the echo of the report 2.5 sec. later. How far away is the cliff?

1229. Sometimes a steamer in mid-ocean gets so near an iceberg as to produce an echo when the whistle blows. How near is the iceberg if 7 sec. elapse between the blast and its echo?

1230. When a person stands in a certain position, a large barn 800 ft. away sends back the echo of his voice. What time elapses between the shout and the echo?

1231. Compare the intensity of sound at a distance of 10 ft. from its source, with the intensity at a distance of (*a*) 20 ft.; (*b*) 30 ft.; (*c*) 35 ft.

FREQUENCY AND WAVE LENGTH

1232. What is the length of a sound wave given off by a tuning fork which vibrates 320 times per second?

1233. The tone sometimes called low C in music has 128 vibrations per second. (*a*) How long in feet are the sound waves given out? (*b*) When the octave of this tone is struck, what is the wave length of the sound produced?

1234. Find the vibration number of a violin string that sends out sound waves 3 ft. long.

1235. An organ pipe sends out sound waves 8 m. long at a temperature of 15° C. What is the vibration number of the pipe?

1236. If the vibration number of C′ is 512, compute the number for the tones D′, E′, and G′ on the diatonic scale.

1237. If the vibration number of C′ is 512, calculate the wave length of the tone A′ on the diatonic scale.

1238. The vibration number for C is sometimes taken as 264. With this as the keynote find the frequencies of the next seven tones on the major diatonic scale.

1239. How many beats per second are produced by two tones that have vibration rates of 280 and 285?

1240. A piano tuner succeeds in getting two unison strings in a piano so that 3 beats per second are heard when the key is struck. If the vibration number of one of the strings is 320 per second, what is the number of the other?

RESONANCE AND ORGAN PIPES

1241. A tuning fork which makes 180 vibrations per second is to be vibrated over a tall glass jar to illustrate the principle of reënforcement of sound. To get the best results, how deep in inches should the jar be? Neglect the diameter of the jar.

1242. The vibration number of a certain tuning fork is 300. Find the length in centimeters of a tube that will produce maximum resonance with this fork when the temperature is 20° C. Neglect the diameter of the tube.

1243. A vibrating tuning fork is held over the mouth of a tall glass jar, and water is poured into the jar until the maximum reënforcement of the sound is produced. The length of the air column in the tube is found to be 15 in. What is the vibration number of the fork?

1244. The frequency of a vibrating tuning fork is to be found by holding it at the mouth of a long tube that is fitted

with a movable piston. When the greatest resonant effect is produced, it is found that the distance from the piston to the mouth of the tube is 20 cm.

1245. (*a*) How long must a closed organ pipe be to produce waves 6 ft. long? (*b*) How long must an open pipe be to produce the same length waves?

1246. Find (approximately) the length of the sound wave given out (*a*) by a closed organ pipe 8 ft. long; (*b*) by an open pipe of the same length. (*c*) How long would the open pipe have to be to produce the same wave length as the closed pipe?

1247. Find the approximate length of the sound waves given out (*a*) by an open pipe 10 ft. long; (*b*) by a closed pipe of the same length. (*c*) How long would the closed pipe have to be to produce waves of the same length as those of the open pipe?

1248. A closed pipe, to have a frequency of tone of 64, must be approximately 4.25 ft. long. (*a*) Find the frequency of an open pipe of the same length. (*b*) What must be the length of an open pipe to have a frequency of 64?

1249. An open pipe to have a tone frequency of 32 must be approximately 17 ft. long. (*a*) Find the tone frequency of a closed pipe of the same length. (*b*) How long must a closed pipe be to give the same tone as the open pipe just referred to?

1250. A closed pipe 32.5 cm. long gives a tone sometimes called "middle C," frequency 256. Find the pitch of an open pipe 65 cm. long.

1251. An open pipe 21 in. long gives the tone called D♯, frequency 300. Find the pitch of a closed pipe 42 in. long.

VIBRATING STRINGS

1252. A certain string makes 100 vibrations per second. If the tension remains the same, what will the number be when the string is made (*a*) only half as long? (*b*) three fifths as long? (*c*) How long should the string be to make the tone two octaves above the original tone?

1253. A string 1 m. long has a vibration frequency of 256. (*a*) What will be the frequency if the string is made 75 cm. long? (*b*) What wave length will it produce?

1254. The length of a violin string from bridge to end of finger board is 33 cm. The vibration frequency of the D string is 288. (*a*) How far from the bridge must the finger be pressed to produce the D′ above? (*b*) to produce G ($n = 348$)?

1255. The diameters of two strings are 0.75 mm. and 2.25 mm. The vibration frequency of the first string is 150. Find the frequency for the second string.

1256. A wire 2.8 mm. in diameter vibrates 280 times per second. Find the vibration number of another wire in all respects like the first one, except that its diameter is 0.8 mm.

1257. Two strings of the same material are stretched with the same tension. One string is 90 cm. long and 1.2 mm. in diameter; the other is 60 cm. long and 1.5 mm. in diameter. If the first string makes 300 vibrations per second, how many does the other one make?

1258. What change is made in the vibration frequency of a wire if the tension is made (*a*) 4 times as great? (*b*) $\frac{1}{3}$ as great? (*c*) twice as great?

1259. The wire on a sonometer passes over a pulley at one end of the scale and is stretched by a 25-lb. weight. How heavy must the weight be to make the tone (*a*) an octave higher? (*b*) an octave lower?

1260. A wire 80 cm. long, 0.9 mm. in diameter, vibrates with a frequency of 400, when the tension is 25 lb. Find the frequency of another wire of the same material, 120 cm. long, 1.2 mm. in diameter under a tension of 100 lb.

1261. A string 150 cm. long and 1.8 mm. in diameter gives out the tone B($n = 480$) when tuned up to a tension of 225 lb. What tension must be put upon a string of the same material, 125 cm. long and 0.9 mm. in diameter, so that it may give out the tone G($n = 384$)?

SOUND MISCELLANY

1262. Describe the determination of the velocity of sound in air by the resonance tube method.

A wire 96 cm. long makes 128 vibrations per second under a certain tension. What must the length become, if the number of vibrations is to become 512 per second while the tension remains constant? [Princeton.]

1263. Describe the character and the method of production of Chladni's sound figures.

Or,

Explain how and why the apparent pitch of the whistle of an approaching locomotive differs from that of the whistle of the same locomotive receding. [Harvard.]

1264. What is the nature of the disturbance which causes the sensation of sound? How is it propagated? Define wave length, frequency, and velocity. What properties of a medium affect the velocity of sound disturbances in it? [Dartmouth.]

1265. About how fast do sound waves travel? Explain how the laws of vibrating strings are illustrated in a violin or piano. [Cornell.]

1266. Tell the vibration frequencies of the notes E and G in the gamut which begins with 128 vibrations for the lower C. [Harvard.]

1267. What is meant by resonance? Give two distinct examples. [Dartmouth.]

1268. How can you show experimentally that sound is transmitted by the air, but not by the ether?

What experimental proof can you give that sound waves can be reflected? [Princeton.]

1269. Tell some of the most important differences between sound waves and light waves. [Harvard.]

1270. What are the three characteristics of a musical note? What characteristics of the vibrating body determine these? What are overtones? Which of the characteristics of the musical note do they affect? Explain the occurrence of beats. [Dartmouth.]

1271. A tuning fork produces a strong resonance when held over a jar 15 in. long. (*a*) Find the wave length of the sound of the fork. (*b*) Find the number of vibrations per second, the velocity of sound being taken as 1100 ft. per second. Ignore the influence of the diameter of the jar. [Harvard.]

1272. How is sound propagated (*a*) in air? (*b*) in water? Define wave length, frequency, and velocity. What relations exist between these quantities? [Dartmouth.]

ELECTRICITY

ELECTRO-CHEMICAL EQUIVALENT

1273. How many grams of silver will be deposited from a solution of silver nitrate by a current of 2 amperes in 50 sec.?

1274. How many grams of copper will be deposited from a bath of copper sulphate by a current of 5 amperes in 30 min.?

1275. How much would a metal platter increase in weight, if it were nickel-plated by a current of 0.5 ampere running 5 hr.?

1276. What is the current strength of a Daniell cell, if its copper plate gains 0.7 g. in 40 min.?

1277. How much current would be needed to make in 3 hr. a copper electrotype shell weighing 40 g.?

1278. How long would a current of 5 amperes have to run to deposit 0.6 g. of silver on a metal spoon?

1279. How long would it take a current of 5 amperes to produce 0.6 g. of hydrogen by decomposition of water? Compare result with that in last example.

1280. Find the electro-chemical equivalent for zinc, from the fact that one of the zinc plates in an Edison chemical meter gains 726 g. when 20 amperes passes through it for 30 hr.

1281. If a current of 2 amperes is used to decompose water, and produces 2.981 g. of oxygen in 5 hr., what is the electro-chemical equivalent for oxygen?

OHM'S LAW

1282. How many amperes will an electro-motive force of 10 volts send through a resistance of 4 ohms?

1283. What current will a pressure of 50 volts send through a wire, the resistance of which is (*a*) 10 ohms? (*b*) 300 ohms?

1284. Sixteen candle power incandescent lamps often have, when lighted, a resistance of 220 ohms; how much current is passing through one of them, if the electro-motive force is 110 volts?

1285. If a telegraph wire has a resistance of 300 ohms, how many amperes will be sent through it by a pressure of 10 volts?

1286. The combined resistance of two relays and 20 mi. of telegraph wire is 500 ohms. If the total voltage of the line battery is 25, how strong a current would pass over the line?

1287. A dry cell has an E.M.F. of 1.3 volts and an internal resistance of 0.06 ohm. How strong a current will it produce (*a*) if it is "short circuited" by a short, thick wire of 0.01 ohm resistance? (*b*) if its terminals are connected by a wire of 10 ohms resistance? (*c*) If any one should ask you how much current a dry cell gives, what would be your answer? (*d*) Dealers usually guarantee a new cell to give say 20 amperes. Under what conditions would this guarantee hold? Would the cell give 20 amperes continuously?

1288. What current will flow if the terminals of a 110-volt dynamo are connected (*a*) by a lamp of 220 ohms resistance? (*b*) by a wire of 110 ohms resistance? (*c*) by a bar of copper of 0.01 ohm resistance?

NOTE. — In problems 1289 to 1298 inclusive, find the values of the missing quantities:

	E	R	r	C
1289.	100	5	—	?
1290.	?	0.1	—	200
1291.	60	?	—	4
1292.	225	11	?	20
1293.	80	?	0.6	80
1294.	15	5	0.3	?
1295.	?	90	5	6
1296.	40	?	3	12
1297.	5	0.02	?	130
1298.	?	5	0.1	0.2

1299. How large an E.M.F. is needed to send a current of 5 amperes through a wire the resistance of which is (*a*) 1 ohm? (*b*) 9 ohms?

1300. The hot resistance of an incandescent lamp is 100 ohms. The current required to bring it to incandescence is 1.1 amperes. How great must the E.M.F. be?

1301. With the average person death is likely to ensue if 0.1 ampere pass through the body. The resistance of the body varies greatly with different people. What voltage would be fatal to a person whose body resistance is (*a*) 2000 ohms? (*b*) 10,000 ohms?

1302. The resistance of the wires in an electric heater is 12 ohms. They will stand 10 amperes before becoming unduly heated. How high can the voltage be?

1303. The resistance of a motor is 3 ohms, and a current of 20 amperes is needed to run it properly. For what voltage is the motor designed?

1304. What is the resistance of a circuit, if 110 volts is required to send a current of 5 amperes through it?

1305. What is the resistance of a telegraph sounder, if it takes 5 volts to send a current of 0.5 ampere through it?

1306. What is the resistance of the electric light circuit of a factory, if the voltmeter at the dynamo reads 100 volts and the ammeter 60 amperes?

1307. A lifting magnet receives the 6 amperes it needs to lift a certain load, if it is connected to a 60-volt circuit. (*a*) What is its resistance? (*b*) If this magnet were connected to a 110-volt circuit, how many amperes would pass through it?

1308. If the voltage of a certain circuit were doubled, what effect would that produce (*a*) upon the current strength? (*b*) upon the resistance? (*c*) What change must be made in the resistance to keep the current strength unaltered?

1309. If the resistance of a certain circuit were made one third as great, how would that affect (*a*) the current strength? (*b*) the voltage? (*c*) What change must be made in the voltage to keep the current strength unaltered?

1310. A cell has an E.M.F. of 2 volts and an internal resistance of 0.3 ohm. If the poles of this cell are joined by a wire which has a resistance of 7.7 ohms, what current will be produced?

1311. The external resistance of a battery is 15 ohms and the internal resistance is 0.8 ohm. If the E.M.F. is 6 volts, what will be the strength of the current?

1312. A bichromate cell which has an E.M.F. of 2 volts sends a current of 0.32 ampere through an electric bell which with its connecting wires has a resistance of 6 ohms. Find the resistance of the cell itself.

1313. The voltage of a certain cell is 1.7, and it sends a current of but 0.7 ampere through an external resistance of 2 ohms. Find its internal resistance.

1314. A storage battery which has a total voltage of 9 volts and an internal resistance of 0.03 ohm sends a current of 4 amperes through an electro-magnet. What is the resistance of the magnet and the rest of the external circuit?

OHM'S LAW: DROP IN POTENTIAL

1315. The resistance of a mile of trolley wire is 0.5 ohm. What voltage will be required to send a current of 60 amperes through this line, *i.e.* what will be the *drop in potential* along this line?

1316. The resistance between A and B (Fig. 36) is 5 ohms, between B and C is 10 ohms, between C and D is 27 ohms.

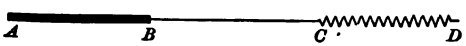

FIG. 36.

If the current flowing is 3 amperes, what is the fall in potential in each of the three sections?

1317. The current flowing from A to D (Fig. 36) is 5 amperes. The drop in potential from A to B is 3 volts, from B to C is 10 volts, and from C to D is 45 volts. Find the resistance of each of the three sections.

1318. An incandescent lamp of 150 ohms resistance, a magnet of 10 ohms resistance, and a rheostat of 20 ohms resistance, are connected in series. (*a*) How much pressure

is needed to send a current of 2 amperes through the circuit? (*b*) What will be the fall in pressure through each part of the circuit?

1319. Figure 37 may be used to represent diagrammatically an incandescent lamp filament, *R*, lighted by a current from the dynamo. An ammeter, *A*, placed in series with the lamp, shows the current strength, and the voltmeter, *V*, connected across the terminals of the lamp, shows the fall in potential through the lamp. From these two readings the resistance of the lamp can be found. This is called the "drop-in-potential" method of finding resistance, and is very commonly used. What is the resistance of this lamp, if the voltmeter reads 55 volts and the ammeter 1.1 amperes?

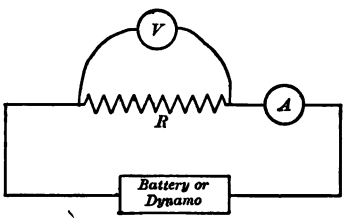

FIG. 37.

1320. The potential difference between the terminals of a telegraph relay, *R* (Fig. 37), is 10 volts. The current flowing through the relay (as shown by the ammeter, *A*) is 0.02 ampere. What is the resistance of the relay?

1321. When a current is put through the field magnets, *R* (Fig. 37), of a motor, the voltmeter, *V*, reads 108, and the ammeter, *A*, reads 0.4. Find the resistance of the field magnets.

LAWS OF RESISTANCE

1322. The resistance of 100 ft. of No. 18 copper wire is 0.66 ohm. Find the resistance (*a*) of 300 ft. of the same size and kind; (*b*) of 3 in.

1323. The resistance of No. 00 trolley wire is 0.081 ohm per 1000 ft. What is the resistance of a line 10 mi. long?

1324. The resistance of 500 ft. of iron wire of a certain size is 40 ohms. How large a resistance would 1200 ft. of it have?

1325. How many feet of wire similar to that in problem 1324 would have to be used to give a resistance of 50 ohms?

1326. The resistance of 1000 ft. of No. 36 copper wire is 432 ohms. How many feet of it should be used in winding a 300-ohm relay?

1327. The resistance of the wire on an electric heater is 30 ohms. Find how many feet of wire it contains, from the fact that the resistance of 10 ft. of this wire is 0.27 ohm.

1328. A wire of a certain size and length has a resistance of 12 ohms. What is the resistance of a wire of the same material and length, but (*a*) of twice the sectional area? (*b*) of one third the sectional area? (*c*) of two ninths the sectional area?

1329. The resistance of a certain length of wire 1.3 mm.^{2} in sectional area is 2 ohms. What is the resistance of a wire of the same length and material, but (*a*) 8.9 mm.^{2} in area? (*b*) 0.16 mm.^{2} in area?

1330. What must be the sectional area of a wire of the same length and material as that in problem 1329 to have a resistance of 5.3 ohms?

1331. The resistance of a piece of wire of 3 mm.^{2} sectional area is 5 ohms. What must be the sectional area of a piece of wire of the same length and material, if the resistance is to be 6 ohms?

1332. A wire of a certain size and length has a resistance of 18 ohms. What is the resistance of a wire of the same material and length, but (*a*) of twice the diameter? (*b*) of one third the diameter? (*c*) of three quarters the diameter?

1333. The resistance of a certain length of wire 0.57 mm. in diameter is 3 ohms. Find the resistance of a wire of the same material and length, but (*a*) 2.6 mm. in diameter; (*b*) 0.45 mm. in diameter.

1334. What must be the diameter of a wire of the same length and material as that in problem 1333 to have a resistance of 4 ohms?

1335. The resistance of a piece of wire 3 mm. in diameter is 5 ohms. What must be the diameter of a piece of wire of the same length and material if the resistance is to be 6 ohms? Compare this problem with problem 1331.

1336. The resistance of 1000 ft. of wire 2.3 mm.^{2} in area is 4 ohms. Find the resistance of 3000 ft. of the same kind of wire 2.9 mm.^{2} in area.

1337. The resistance of 300 m. of wire 1.3 mm. in diameter is 7 ohms. Find the resistance of a piece of this same kind of wire 60 m. long and 0.51 mm. in diameter.

1338. Twenty feet of a certain kind of wire has a resistance of 3 ohms when the wire is of such a size that its sectional area is 1.3 mm.^{2} Thirty feet of another size of the same kind of wire has a resistance of 2 ohms. Find the sectional area of this second wire.

1339. Twenty feet of a certain kind of wire has a resistance of 3 ohms when the wire is of such a size that its diameter is 1.3 mm. Thirty feet of another size of the same kind of wire has a resistance of 2 ohms. Find the diameter of this second wire.

1340. How many feet of wire 3.4 mm.^{2} in area would have the same resistance as 100 ft. of the same kind of wire 2.1 mm.^{2} in area?

CIRCULAR MIL AND MIL-FOOT

NOTE. — In practical work it is customary to express the diameter of a round wire in mils and the area in circular mils. A mil is equal to 0.001 in. A circular mil is the area of a circle which has a diameter of 1 mil. When the diameter of a round wire in mils is known, the area in circular mils may be found by squaring the diameter; *e.g.* if the diameter of a round wire is 5 mils, its area is 25 circular mils.

1341. The diameter of a certain wire is 0.025 in. Find (*a*) its diameter in mils; (*b*) its area in circular mils.

1342. Find (*a*) the diameter in mils, and (*b*) the sectional area in circular mils, of wires having the following diameters: (1) .001 in.; (2) .012 in.; (3) .0201 in.; (4) .0285 in.; (5) .0403 in.

1343. The sectional area of a wire is 75,000 circular mils. Find its diameter (*a*) in mils; (*b*) in inches.

1344. The sectional area of a certain wire is 8234 circular mils. Find its diameter (*a*) in mils; (*b*) in inches. (*c*) Verify the answer by consulting the wire table in the Appendix.

NOTE. — The resistance of a piece of copper wire that has a sectional area of one circular mil and a length of one foot is about 10.5 ohms. This is called the resistance of a *mil-foot* of copper, and should be memorized.

1345. Find the resistance (*a*) of a 100-ft. piece of copper wire that has a sectional area of 1 circular mil; (*b*) of a 100-ft. piece of copper wire that has a sectional area of 10 circular mils.

1346. The cross section of No. 8 wire is 16,500 circular mils. Find the resistance of 1500 ft. of this size copper wire.

SOLUTION

$$R = 10.5\frac{l}{a}$$

$$= \frac{10.5 \times 1500}{16500}$$

$$= 0.95 \text{ ohm}$$

1347. Find (using tables in Appendix) the resistance of 1000 ft. of copper bell wire No. 18.

1348. Find the resistance of a mile of No. 00 trolley wire (always copper).

1349. What is the resistance of 2000 ft. of No. 6 iron telegraph wire? (See Appendix, relative resistances.)

1350. How many feet of No. 20 copper wire must be used to produce a resistance of 5 ohms?

1351. How many feet of No. 20 German silver wire will have to be used to make a rheostat that is to have a total resistance of 30 ohms?

1352. What must be (*a*) the area in circular mils, and (*b*) the diameter in mils, of a copper wire 100 ft. long, if it is to have a resistance of 10.5 ohms?

1353. Two hundred feet of copper wire has a resistance of 5.25 ohms. Find the diameter of this wire in inches.

1354. The resistance of a certain power line 10,000 ft. long must not exceed 5 ohms. (*a*) What should the area be in circular mils? (*b*) What is the smallest size wire (Brown & Sharpe gauge) that can be used?

1355. The drop in potential is to be 10 volts over a power line a mile long when a current of 5 amperes is passing. What size copper wire shall be used (Brown & Sharpe gauge)?

1356. What voltage would be needed to send a current of 3 amperes a distance of 2000 ft. over (*a*) a No. 8 copper wire? (*b*) a No. 8 iron wire?

1357. A coil of German silver wire is put in series with an arc lamp so that the lamp, which requires 5 amperes at a pressure of 85 volts, may be used on a 110-volt circuit. This means that 25 volts drop must take place in the coil. How many feet of No. 16 wire must be used?

JOINT RESISTANCE

1358. (*a*) Find the resistance of 100 ft. of No. 30 copper wire. (*b*) Find the joint resistance of two 100-ft. lengths of No. 30 copper wire joined in multiple. (*c*) What should be the area of a single copper wire 100 ft. long to have the same resistance as the two wires in (*b*)? (*d*) What would be the gauge number of this wire?

1359. Two wires, each having a resistance of 13 ohms, are joined in multiple. (*a*) If the current that flows through the main circuit is 10 amperes, how much goes through each wire? (*b*) What is the joint resistance of the two wires?

1360. Five incandescent lamps, each having a resistance of 220 ohms, are connected in multiple as shown in Figure 38. (*a*) If the current through the ammeter, *A*, in the main line is 2.5 amperes, how much of this current flows through each lamp? (*b*) What is the joint resistance of the five lamps?

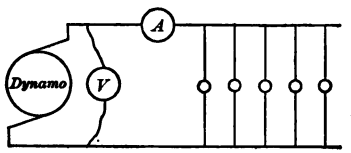

FIG. 38.

1361. Twenty incandescent lamps, each of 200 ohms resistance, are connected in parallel (see Fig. 38). Each lamp must have a current of 0.55 ampere to bring it to proper incandescence. (*a*) How strong a current will the ammeter, *A*, register? (*b*) What is the joint resistance of the twenty lamps?

1362. Two wires, having resistances of 5 ohms and 10 ohms respectively, are joined in multiple (or parallel) and connected to the terminals of a Daniell cell. In what proportion will the current divide between the two wires?

1363. A galvanometer, the resistance of which is 300 ohms, has a short wire of 1 ohm resistance connected across its

terminals. If the galvanometer is now used, what fraction of the total current will pass through it?

1364. (*a*) A resistance of 7 ohms and one of 3 ohms are connected in series. What is their joint resistance? (*b*) If they are connected in multiple, what will be their joint resistance?

1365. Find the joint resistance of two wires connected in parallel, if their separate resistances are 8 ohms and 12 ohms.

1366. A parallel circuit consists of three branches of 3, 4, and 6 ohms respectively. Find the joint resistance.

1367. A wire has a resistance of 25 ohms. When joined in multiple with another wire, their combined resistance is only 5 ohms. Find the resistance of this other wire.

1368. The joint resistance of two wires in parallel is 6 ohms. If the resistance of one of them is 11 ohms, (*a*) what must be the resistance of the other? (*b*) The 11-ohm wire is No. 36 copper. How long is it?

1369. The separate resistances of two incandescent lamps are 210 ohms and 70 ohms. If they are joined in multiple, what is their joint resistance?

1370. If the lamps in problem 1369, joined in multiple, are connected to a 105-volt circuit, (*a*) how much current will they draw from the circuit? (*b*) how much current will flow through each lamp?

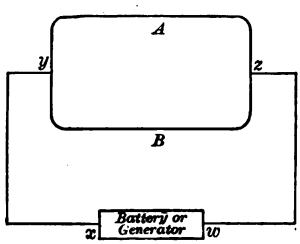

FIG. 39.

1371. The resistance of branch *A* (Fig. 39) is 8 ohms, of branch *B* is 6 ohms, and the fall in potential from *y* to *z* is 96 volts. Find (*a*) the current in *A*; (*b*) the current in *B*; (*c*) the current in *xy*; (*d*) the joint resistance of *A* and *B*.

1372. The terminals of a storage battery are connected by two parallel wires, each having a resistance of 6 ohms. The current through the battery is 10 amperes. Find the drop in potential through the wires.

1373. The resistance of branch A (Fig. 39) is 5 ohms, and the current passing through it is 11 amperes. The resistance of branch B is 4 ohms. Find (a) the difference in potential between points y and z; (b) the current through B; and (c) the current coming from the generator.

1374. The difference in potential between points y and z (Fig. 39) is 90 volts. A is an electric radiator of 10 ohms resistance. When another radiator, B, is turned on, the current in the main line, xy, is increased to 20 amperes. (The potential difference between y and z remains constant.) Find the resistance of radiator B.

1375. A and B (Fig. 39) are two electric bells connected in multiple. The potential difference at their terminals, x and y, is 2 volts. The resistance of bell A is 8 ohms, and the current through bell B is 0.2 ampere. Find (a) the current through bell A; (b) the resistance of bell B.

1376. The joint resistance of two parallel branches, A and B, of a divided circuit is 5 ohms. The current in A is 7 amperes, and in B is 8 amperes. Find the separate resistance of each branch.

1377. A wire of 5 ohms resistance is connected in series with a pair of wires in parallel which have resistances of 6 ohms and 10 ohms. What is the total resistance of the circuit?

1378. In Figure 39, A is an incandescent lamp of 220 ohms resistance; B is another lamp of 110 ohms resistance. The mains, xy and zw, are each 500 ft. of No. 8 copper wire. The resistance of the dynamo is 2 ohms. Find the total resistance.

METHODS OF CONNECTING LAMPS

1379. (*a*) Make a diagram to show 5 100-volt lamps connected in series. (*b*) What must be the voltage of the dynamo that operates these lamps, assuming no other resistance in the circuit? (*c*) If each lamp requires 1.5 amperes, how strong a current must the dynamo supply?

1380. (*a*) Make a diagram to show 5 100-volt lamps connected in multiple. (*b*) What must be the voltage of the dynamo that operates them, assuming no other resistance in the circuit? (*c*) If each lamp requires 1.5 amperes, how strong a current must the dynamo supply?

1381. (*a*) Make a diagram to show how 10 55-volt lamps can be used to light a street car which is operated on a 550-volt circuit. (*b*) By another diagram show how this same car could be lighted by 10 110-volt lamps.

1382. Christmas trees are often lighted by small, low-voltage lamps connected to the ordinary incandescent circuit. Show by a diagram how 20 10-volt lamps could be operated on a 100-volt circuit.

1383. Street cars are often wired so that an electric bell on the platform can be rung by pressing any one of a dozen or more push buttons located on the casing, between the windows. Make a diagram to show how the wiring might be arranged.

1384. How many 0.5-ampere incandescent lamps can be placed on a circuit that is protected by a 10-ampere fuse, if the lamps are connected (*a*) in multiple? (*b*) in series?

1385. Ten incandescent lamps, each of 200 ohms hot resistance, are connected in parallel. The mains from this group of lamps to the dynamo have a total resistance of 2 ohms. If each lamp requires half an ampere to light it, what must be the voltage of the generator? First draw a diagram.

MAGNETIZATION: AMPERE-TURNS

1386. The winding on a telegraph relay consists of 8000 turns of wire, and the current is 0.25 ampere. (*a*) How many ampere-turns produce the magnetizing effect? (*b*) Suggest two ways of doubling the number of ampere-turns.

1387. A circuit consists of a 40-volt battery of negligible resistance, 200 ft. of No. 10 iron telegraph wire, and an electro-magnet made of 2000 ft. of No. 24 copper wire wound in 3000 turns. How many ampere-turns are available?

1388. If the electro-magnet in problem 1387 is replaced by one having a resistance of 70 ohms, how many turns does it have if the number of ampere-turns is 2000?

WHEATSTONE BRIDGE

1389. The resistance of a coil of wire is to be measured by means of a Wheatstone bridge (Fig. 40). It is found that there is no current passing through the galvanometer when the ratio coils R' and R'' are 10 and 1 ohms respectively, and the resistance in the resistance box R is 35.2 ohms. Find the resistance of the coil X.

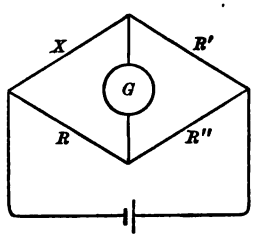

FIG. 40.

1390. The Wheatstone bridge (Fig. 40) is perfectly balanced when $R'=1$ ohm, $R''=1000$ ohms, and $R=4.2$ ohms. Find the value of the unknown resistance X.

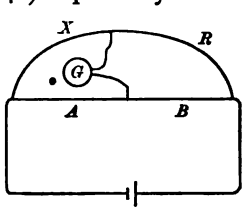

FIG. 41.

1391. A slide wire bridge (Fig. 41) is used to measure the resistance of a spool of wire X. No current flows through the galvanometer when $R=2.6$

ohms, and the distances A and B are 52 cm. and 48 cm. respectively. Find the resistance of the wire.

1392. The slide wire bridge (Fig. 41) is in perfect balance when $R = 7$ ohms, $A = 49$ cm., and $B = 51$ cm. Find the unknown resistance X.

1393. A student using the slide wire bridge (Fig. 41) to measure the resistance of three coils of wire records his data as follows:

Coil	R	A
1	5.2 ohms	48.3 cm.
2	8.4	50.9
3	27.1	51.2

Find the resistance of each coil.

GROUPING OF CELLS

1394. A battery of 3 cells, each having an E.M.F. of 1.6 volts and an internal resistance of 0.5 ohm, is connected in series through an external resistance of 75 ohms. How strong will the current be?

1395. Six cells, each having an E.M.F. of 1.9 volts and an internal resistance of 0.3 ohm, form a series battery to send a current through a bell circuit of 40 ohms resistance. How strong a current will result?

1396. Twenty gravity cells, each of 3 ohms resistance and 1.07 volts E.M.F., are arranged in series to operate a railroad signal, the circuit of which has 150 ohms resistance. What current does the line receive?

1397. A storage battery of 60 cells arranged in series is used to light 10 incandescent lamps arranged in multiple.

Each lamp has a hot resistance of 220 ohms, each cell of the battery a resistance of 0.01 ohm, and the mains have a resistance of 0.4 ohm. The E.M.F. of each cell is 2 volts. What current flows (*a*) from the battery? (*b*) through each lamp?

1398. A current of 0.25 ampere is generally used on telegraph lines. How many gravity cells, in series, each having an E.M.F. of 1.06 volts and a resistance of 2 ohms, would be needed on a line, the total external resistance of which is 400 ohms?

1399. A telegraph line consists of two relays of 150 ohms each and 6000 ft. of No. 10 copper wire. It is operated by gravity cells, each of which has an E.M.F. of 1.07 volts and a resistance of 3 ohms. How many of these must be used in series to produce the required current of 0.25 ampere?

1400. With 3 cells, each having a resistance of 0.1 ohm, and a voltage of 1.5, how much external resistance can be used without reducing the current below 3 amperes, if the cells are joined in series?

1401. The battery of a telegraph line consists of 120 cells in series, each of 2.5 ohms resistance and 1 volt pressure. The current is to be at least 0.2 ampere. (*a*) How great can the external resistance be? (*b*) If the line consists of 3000 ft. of copper wire and two 145-ohm relays, how small (Brown & Sharpe gauge) can the wire be?

1402. A bichromate cell of 2 volts pressure and 0.1 ohm resistance, and a dry cell of 1.4 volts pressure and 0.7 ohm resistance, are connected in series, and send a current through an external resistance of 5 ohms. How strong will this current be?

1403. If the cells described in problem 1402 are connected in opposition to each other, how strong a current will they send through this same external resistance?

1404. Three cells, *A*, *B*, and *C*, have resistances of 0.3, 0.4, and 0.5 ohms, and pressures of 1.3, 1.4, and 1.5 volts respectively. These cells are connected in series to an external resistance of 6 ohms. By some mistake the terminals of *C* are reversed so that it acts in opposition to *A* and *B*. What current will flow through the circuit?

1405. A battery of 6 cells, each having a pressure of 1.3 volts and a resistance of 0.6 ohm, is connected in parallel and sends a current through a short, thick wire of 0.03 ohm resistance. How heavy will the current be?

1406. Four cells, each having an E.M.F. of 1.5 volts and an internal resistance of 0.8 ohm, are connected in multiple to send a current through an external resistance of 0.5 ohm. How strong will the current be?

1407. A storage battery of 5 cells in multiple is used to operate an electroplating bath which has a resistance of 0.04 ohm. Each cell has a resistance of 0.02 ohm and a pressure of 2 volts. What current does the battery furnish?

1408. What current would 10 Daniell cells, arranged in parallel, send through 200 ft. of No. 5 copper wire? Each cell has a pressure of 1.05 volts and an internal resistance of 2 ohms.

1409. How many storage cells, each having a pressure of 1.9 volts and a resistance of 0.03 ohm, must be grouped in multiple to send a current of 40 amperes through an external resistance of 0.04 ohm?

1410. A current of 15 amperes is to be sent through a small wire of 0.08 ohm resistance to heat it to incandescence. How many dry cells should be connected in parallel, if each has an E.M.F. of 1.4 volts and a resistance of 0.3 ohm?

1411. Seven similar cells, each having a resistance of 1.4 ohms, send a current of 2.6 amperes through an external

resistance of 0.3 ohm when they are connected abreast. What is the E.M.F. of each cell?

1412. (*a*) If n cells, each having an electromotive force of E volts, and a resistance of r ohms, are grouped in series, what current will they send through an external resistance of R ohms? (*b*) If the external resistance, R, is so small as to be negligible, what does the answer to (*a*) become?

1413. (*a*) If m cells, each having an electromotive force of E volts and a resistance of r ohms, are grouped in parallel, what current will they send through an external resistance of R ohms? (*b*) If the external resistance, R, is so large that the internal resistance, r, is negligible, what does the answer to (*a*) become?

1414. Ten cells are arranged 5 series and 2 parallel to send a current through an external resistance of 8 amperes. Each cell has a resistance of 0.4 ohm and an E.M.F. of 1.6 volts. Find the current strength.

1415. Six cells, each of 1.4 volts pressure and 0.6 ohm resistance, arranged 3 in multiple and 2 in series, send a current through an external resistance of 5 ohms. How strong is this current?

1416. What current would have been produced if the cells in problem 1415 had been grouped (*a*) 3 in series and 2 in multiple? (*b*) all in series? (*c*) all in multiple?

1417. Twelve cells, each having a pressure of 2 volts and a resistance of 1 ohm, are used to send a current through a wire of 3 ohms resistance. Find the current strength in each of the six possible arrangements.

1418. Twenty cells of 1.5 volts and 0.6 ohm each are used to send a current through a telegraph line which has a resistance of 400 ohms. (*a*) How should the cells be arranged to

give the maximum current? Decide by inspection if possible. (*b*) How strong will this current be?

1419. Ten cells, each having an E.M.F. of 1.5 volts and a resistance of 0.6 ohm, are used to heat a wire that has a resistance of 0.01 ohm. (*a*) How should they be arranged to give the strongest current? Decide by inspection if possible. (*b*) How strong will this current be?

1420. Six cells, each having an E.M.F. of 1.6 volts and a resistance of 1.2 ohms, are to operate a small plating bath which has a resistance of 0.8 ohm. How should they be grouped to make as strong a current as possible?

1421. What arrangement of 30 cells will give the largest current through an electric bell circuit, the total resistance of which (outside the battery) is 5 ohms? Each cell has a pressure of 1.7 volts and a resistance of 0.7 ohm.

1422. How must 6 cells be arranged to send the maximum current through an external resistance of 2 ohms, if each cell has a resistance of 1.4 ohms and an E.M.F. of 1.6 volts?

1423. Twelve cells are to send the largest possible current through 1000 ft. of No. 12 copper wire. Each cell has a pressure of 1.3 volts and a resistance of 0.78 ohm. How should they be grouped?

ELECTRICAL ENERGY

1424. A Daniell cell, voltage 1.06, sends a current of 0.8 ampere through a short wire. At what rate in watts is it furnishing power?

1425. A storage battery, the E.M.F. of which is 40 volts, is operating a lifting magnet which requires 10 amperes. (*a*) What power in watts is being used? (*b*) What is the resistance of the magnet?

1426. The voltmeter across the terminals of a street railway generator reads 550 volts, and the ammeter in the circuit reads 2000 amperes. At what rate is the generator furnishing power?

1427. What is the cost per hour to burn a 16 c.p. 110-volt carbon filament lamp which uses current at the rate of 0.5 ampere, if the electric company charges 15 cts. per kilowatt-hour for power?

1428. An arc lamp runs on 5 amperes at 85 volts pressure. (*a*) At what rate in kilowatts is it using power? (*b*) At 10 cts. per kilowatt-hour, what will it cost to run this lamp 6 hr.?

1429. A 3 K.W. motor is used to operate a printing press, and runs steadily at full load from 8 A.M. till noon. What has been the expense for power, if the cost is 12 cts. per kilowatt-hour?

1430. The output of a certain generator is 25 K.W. If the pressure is 40 volts, what is the current?

1431. How many incandescent lamps, each having a resistance of 100 ohms and requiring a current of 1.1 amperes, can be run by a 10 K.W. generator?

1432. Five arc lamps, each requiring 40 volts at 10 amperes, are run on a *multiple* circuit as in Fig. 42. Neglecting the resistance of the mains, what must be the reading of the voltmeter, *V*, (*a*) if all the lamps are turned on? (*b*) if only three are lighted? What must be the reading of the ammeter, *A*, (*c*) if all the lamps are on? (*d*) if only two are lighted? (*e*) If all the lamps are on, what current is passing

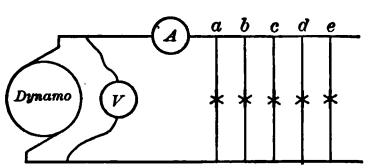

FIG. 42.

between b and c? (f) If all the lamps are lighted, what power is the generator furnishing?

1433. The five arc lamps of problem 1432, each requiring 40 volts at 10 amperes, are run on a *series* circuit as in Figure 43. Neglecting the resistance of the mains, when the lamps are lighted what must be the reading (a) of the voltmeter? (b) of the ammeter? (c) At what rate is the generator furnishing power? (d) Compare the result in (c) with the result in (f) in the last problem.

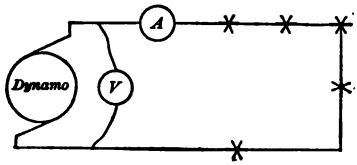

FIG. 43.

1434. The current required for a large vat for electrotyping is 200 amperes. If the total resistance of the circuit is is 0.1 ohm, what must be the output of the generator (a) in watts? (b) in horse power?

1435. (a) Find the horse power of a motor that, when running at full load, requires 20 amperes at 110 volts. (b) At 12 cts. per kilowatt-hour, what does it cost to run this motor?

1436. Find the cost of running a 3 h.p. motor 5 hr. at full load, if the price paid for power is 10 cts. per kilowatt-hour.

1437. A generator is run by a 50 h.p. engine; if the efficiency of this generator is 80 %, what is its output in kilowatts?

1438. A series arc-light circuit (Fig. 43) consists of 40 lamps, each requiring 10 amperes at 45 volts. The mains consist of 5000 ft. of No. 10 copper wire. (a) What must be the capacity of the generator in kilowatts? (b) If this generator has an efficiency of 90 %, what must be the horse power of the turbine that runs it?

1439. A conductor having a resistance of 3 ohms carries a current of 8 amperes. How much heat is developed (*a*) in 1 sec.? (*b*) in 50 min.?

1440. How many calories of heat are produced in 1 min. in a wire of 10 ohms resistance, if it carries a current (*a*) of 5 amperes? (*b*) of 10 amperes? (*c*) if the current is 5 amperes and the resistance is 20 ohms instead of 10 ohms?

1441. What effect is produced in the amount of heat developed in a wire (*a*) if the resistance is trebled? (*b*) if the current is trebled? (*c*) if the voltage is trebled?

1442. (*a*) How much heat is produced in an hour by a current of 40 amperes passing through a wire of 5 ohms resistance? (*b*) What is the smallest size copper wire that can safely carry this current? (See tables.)

1443. How much heat is produced per hour by an 80-volt arc lamp through which a current of 5 amperes is passing?

1444. If a 110-volt incandescent lamp is submerged for 20 min. in 300 g. of cold water while a current of 0.5 ampere is flowing, how many degrees Centigrade will the temperature of the water be raised?

1445. (*a*) Find the resistance of a 10-ampere radiator if it develops 864,000 calories of heat per hour. (*b*) For what voltage is this radiator intended?

1446. A kilogram of water is to be heated from 10° C. to 70° C. in 20 min. by a coil of wire, the resistance of which is 50 ohms. What voltage must be impressed upon the terminals of the coil?

INDUCTION

NOTE. — In the following problems it is well, whenever possible, to make a diagram of the two circuits, and to write in at once all values given in the problems, and all other values as soon as they are found. Disregard the losses that occur in transformation.

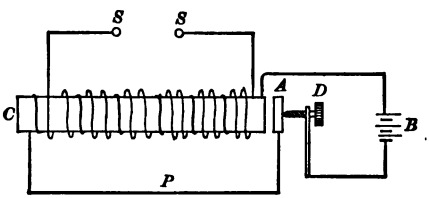

FIG. 44.

1447. The primary of an induction coil (Fig. 44) has 200 turns, and the secondary 18,000 turns. The pressure of the primary current is 10 volts. Find the number of volts induced in the secondary.

1448. If the strength of the current in the primary in problem 1447 is 9 amperes, how many amperes does the secondary produce?

1449. The secondary of an induction coil (Fig. 44) has 5000 turns, and has an alternating current of 1000 volts average pressure induced in it. What would have been the pressure induced if the number of turns had been (*a*) 15,000? (*b*) 2000?

1450. If the primary winding of a transformer (Fig. 45) has 400 turns, and the secondary has 1000 turns, what voltage will be induced in the secondary by a primary voltage of 200?

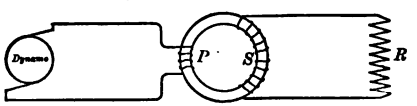

FIG. 45.

1451. In problem 1450, (*a*) how many volts per turn are impressed on the primary winding? (*b*) how many volts per turn are induced in the secondary winding?

1452. The primary pressure of a transformer (Fig. 45) is 1000 volts and the primary winding has 1500 turns. If the

secondary pressure is to be 50 volts, how many turns must there be in the secondary winding?

1453. A current of 10 amperes at a pressure of 20 volts passes through the 200-turn primary of an induction coil. Assuming that there are no losses, how strong a current will be induced in the secondary if it has (*a*) 400 turns? (*b*) 1000 turns? (*c*) What will the voltage be in each case?

1454. The primary of an induction coil has 300 turns and the secondary 60,000 turns. If the primary carries a current of 5 amperes at a pressure of 10 volts, what will be (*a*) the current, (*b*) the voltage, in the secondary?

1455. The secondary of an induction coil consists of 50,000 turns of wire, and a current of 2500 volts and 0.016 ampere is induced in it by a primary current of 5 volts pressure. Find (*a*) the number of turns on the primary; (*b*) the current strength of the primary.

1456. The primary of a small transformer has 150 turns and carries a current of 5 amperes at an average pressure of 110 volts. The secondary has 300 turns. (*a*) How strong is the induced current in amperes? (*b*) How many 110-volt lamps in series will it light?

1457. If the secondary of the transformer in problem 1456 has 75 turns, (*a*) how many 0.5 ampere lamps in multiple will it operate? (*b*) what should be the voltage of these lamps? Assume that the conditions in the primary remain as they were.

1458. The transformer in problem 1456 can be used for electric welding if the secondary has a very small number of turns. Find how strong the current will be if the conditions in the primary remain the same and the secondary has only one turn.

1459. The generator, *G* (Fig. 46), at a small power house produces current of 100 volts and 200 amperes, which passes through the 50-turn primary of a transformer. The second-

FIG. 46.

ary of this transformer has 2000 turns. If there are no losses, what will be the pressure and strength of the secondary current?

1460. The secondary current induced in the transformer in problem 1459 passes through the street mains to the small transformer in front of a factory. Here it passes through a primary of 3000 turns. How many turns must the secondary have if the subscriber's voltage is to be 50?

1461. A transformer having a primary of 800 turns is used to transform an alternating current of 1200 volts down to one of 60 volts. (*a*) How many turns must there be on the secondary? If, then, 100 60-volt lamps, each requiring 1 ampere, are to be operated on this circuit, (*b*) how should they be arranged? (*c*) how many amperes would flow through the primary?

1462. (*a*) Draw a diagram to show how 12 20-volt lamps can be operated on the transformer in problem 1461 without making any change in the windings. (*b*) In this case how many amperes will flow through the secondary if each lamp requires 0.25 ampere? (*c*) How many amperes will flow through the primary?

ELECTRICITY MISCELLANY

1463. What is the source of the electric energy from a dynamo-electric machine? Describe the construction of a dynamo, naming its essential parts and stating the function of each part. [Dartmouth.]

1464. Define the following electrical terms: *ampere, volt, ohm, watt.* Illustrate by reference to any familiar cases in which you know approximately the number of amperes, volts, etc., used. [Harvard.]

1465. Show how you would use an electroscope to determine the sign of the charge of an electrified body.

What is the law of the generation of heat in an electrical circuit?

What is the shape of the lines of force about a straight conductor carrying a current? [Princeton.]

1466. A galvanic cell having an electromotive force of 2 volts and an internal resistance of 1 ohm sends a current of 0.5 ampere through an external circuit consisting of a single wire. (*a*) How great is the external resistance of the circuit? (*b*) How great would be the current, if the external wire were replaced by another of the same material and quality twice as long and twice as thick? [Harvard.]

1467. The electrochemical equivalent of silver is .001118. How much silver will be deposited in one day by a current of 10 amperes?

Make a diagram and explain the action of the induction coil, or transformer. [Princeton.]

1468. A certain galvanic battery consists of two rows of three cells each. The cells in each row are connected in series. The two rows are joined in multiple. The electromotive force of each cell is 1 volt. The resistance of the

circuit outside the battery is 12 ohms. The current which is sent through this resistance by the battery is 0.2 ampere.

(*a*) How great is the resistance of the whole battery?

(*b*) How great is the resistance of each cell? [Harvard.]

1469. Why is iron used in the construction of an induction coil? Explain briefly one important application of such a coil. [Cornell.]

1470. Of what, essentially, does a dynamo consist?

What determines the voltage it can give? What is the purpose of the commutator?

State three ways in which an induced current can be set up. [Princeton.]

1471. Two wires are kept at a difference of potential of 500 volts. The current flows from one wire to the other through 40 arc lamps, each having a resistance of 5 ohms and each requiring a current of 10 amperes. Show by a diagram how the lamps must be arranged to give the right conditions for working. [Harvard.]

1472. What are induced currents? How may they be produced? How may their direction be predicted? What is the source of the energy of induced currents? [Dartmouth.]

1473. The electrochemical equivalent of silver is .001118. How much of that metal will be deposited by a current of 1000 amperes in 5 hr.?

Change 1000 kilowatts to watts; to horse power; to ergs per second. [Princeton.]

1474. Make a very simple diagram illustrating the connection of the principal parts in a "shunt-wound" electric motor or dynamo. (Do not try to make a *picture* of the machine; but *name* the parts indicated in your diagram.) [Harvard.]

1475. State Ohm's Law. What properties of a conducting circuit vary its resistance? What current will flow in a circuit consisting of 10 cells in series, each having an internal resistance of 2 ohms and an E.M.F. of 1.5 volts, 200 ft. of copper wire, resistance 0.02 ohm per foot, and two telegraph instruments with a resistance of 20 ohms each? [Dartmouth.]

1476. Discuss the transformation and conservation of energy as illustrated in the telephone. [Sheffield.]

1477. If a 2000 c.p. arc lamp requires a current of 10 amperes maintained by an electromotive force of 50 volts:

(*a*) How many watts are used per candle power?

(*b*) How much electrical horse power is required to maintain such a lamp in action? [Harvard.]

1478. State Ohm's Law and define meaning of terms used. What must be increase in current in wire to double heating effect? [M.I.T.]

1479. Three wires, *A*, *B*, and *C*, are joined together and to an electric cell in such a way that the current through *A* is twice the current through *B* and five times the current through *C*. What is the ratio of the three resistances? Draw a diagram showing the arrangement, and indicate by numbers the relative resistances, each wire being also lettered. [Harvard.]

COLLEGE ENTRANCE EXAMINATION PAPERS

Massachusetts Institute of Technology

[NOTE. — The following heading appears on each paper.]

Time: two hours.

Physical laboratory notebooks are required in connection with this paper except for candidates coming from schools which are not able to meet the laboratory requirement, in which case a statement to that effect from the principal is required. Notebooks should be left at the Registrar's office, unless this has been done already.

The numerical work as well as the answer is required in the solution of problems.

JUNE, 1905

1. Define and illustrate meaning of terms: *inertia*, *momentum*, *velocity*, *density*, and *resultant force*. If two bodies, whose masses are in the ratio 6 : 8, are acted upon by two equal forces for the same length of time, what will be the ratio of their final velocities?

2. A weight of 100 lb. hangs from one end of the rod 8 ft. long which is pivoted 3 ft. from this end. Calculate the weight required at the other end to keep the rod horizontal. (Neglect weight of rod.)

3. How does uniform motion differ from uniformly accelerated motion, and under what circumstances is each produced? A well is 490 m. deep. How long will it take a stone to reach the bottom, if the acceleration of a falling body is 9.8 m.?

4. What is meant by a 6 h.p. engine? State kind of energy, kinetic or potential, present in the following cases: compressed spring, wheel of a moving car, water in reservoir, swinging pendulum.

5. If a bent U-tube contains mercury and water, show by diagram arrangement of the liquids for equilibrium. What is the specific gravity of a solid that weighs 10 g. in the air and 0 g. in water?

6. If a solid is heated from a temperature below its melting point to one above its boiling point, what will be the phenomena observed with a thermometer?

7. How does the intensity of a sound vary with the distance, and why? Define pitch of a sound. Construct the image of an object in a plane mirror. Is this image real or virtual?

8. State phenomena of electrification by friction. What are induced currents? Give an illustration of their production.

9. Describe three practical arrangements of 8 voltaic cells whose E.M.F. is 1.2 volts each, and internal resistance 8 ohms each. If the external resistance is 40 ohms, will the current be greater with cells in series or in parallel? Why?

SEPTEMBER, 1905

1. Define center of gravity and explain its relation to the stable and unstable equilibrium of suspended bodies. Define mass, density, weight, and illustrate each.

2. If a body falls 176.4 m. in 6 sec., what is its acceleration? How far will it fall during the first 4 sec.? What will be its velocity at the end of 6 sec.?

3. How does the time of vibration of a pendulum vary as the pendulum is carried up a mountain? Why? If the pendulum of a clock be lengthened, will the clock lose or gain time? Give reasons for answer.

4. Explain principle and construction of a mercurial barometer. What would be the effect of using water instead of mercury in the barometer?

5. The volume of a mass of air under a pressure of 75 lb. per square inch is 100 cu. in. What will its volume become if the pressure is increased to 100 lb. per square inch?

6. How does evaporation differ from boiling? What effect has pressure on the boiling point of a liquid? Illustrate.

7. Construct the image of an object placed between the principal focus and twice the focal distance of a double convex lens. State phenomena observed on the passage of a ray of light through a prism.

8. Explain process of charging a Leyden jar. Why does the addition of turns of wire about the needle of a galvanometer increase its sensitiveness for the same current?

9. If it takes 100 volts to generate a current of 21 amperes through a resistance of 5 ohms, what electro-motive force will be necessary to generate $\frac{1}{4}$ the current through a resistance of 10 ohms?

JUNE, 1906

1. If a force of 60 units, acting on a mass of 12 units, generates 180 units of momentum in 3 sec., what force would produce the same momentum in $\frac{1}{100}$ sec.?

What is meant by the statement, "The velocity of a freely falling body is 160 ft. per second at the end of 5 sec. from rest"?

2. The leaning tower of Pisa is inclined 14 ft. from the vertical. Why does it not fall?

Explain necessity of "banking" the curves of a bicycle track.

3. Forces 6, 5, 8 acting on a pivoted body at perpendicular distances 5, 3, 4 respectively from the pivot, tend to produce rotation in same direction. How must a force of 11 be applied to preserve equilibrium?

Will the height to which a body rises above its starting point, when projected vertically upward with a velocity V, be the same at the base as at the top of a lofty mountain? Explain.

4. How much energy does a mass weighing 2 T. acquire in falling through 100 ft.?

If the specific gravity of a solid whose volume is 25 cc. is 0.8, calculate the volume and weight of water that it will displace when floating.

5. A tube 10 ft. long and closed at one end is filled with water. If this tube is placed in a vertical position with the open end under water, why does not the water run out of the tube?

Do sounds of different pitch travel in air with the same velocity? Give reasons for answer.

6. Why does a lake freeze from the surface downward? Would a mass of molten lead, on cooling, also solidify from surface downward? State clearly.

7. What is the difference between the phenomena of reflection from white blotting paper and from a piece of window glass?

Why is the beam of a powerful search light visible at night?

Where would you place an object with a spherical concave mirror to obtain (*a*) a real magnified image? (*b*) a virtual image?

8. How will a permanent magnet place itself if suspended? How will it place itself (*a*) if another suspended magnet is

brought near it? (*b*) a suspended piece of iron? (*c*) a suspended piece of zinc? Explain two methods of magnetizing a piece of steel.

9. Explain cause of divergence of leaves of a gold-leaf electroscope on the approach of a charged body.

What effect have the size of the plates in a voltaic cell and their distance apart on (*a*) the resistance of the cell? (*b*) the potential of the cell?

SEPTEMBER, 1906

1. Resolve a force of 90 lb. into two components at right angles to each other, one being three times the other. Explain an arrangement of pulleys for raising 500 lb. by a force of less than 500 lb.

2. State Newton's three laws of motion. Illustrate each.

3. What is a resultant force? Illustrate.

A body of mass, M, is given an original velocity, V. If a constant force, F, opposes the motion, write out the formula for the velocity of the body at end of time, t.

4. Under what circumstances does a force acting upon a body do work? What measures the amount of work? Will it require 6 h.p. to do 198,000 ft.-lb. of work? Explain.

5. Explain principle of the siphon. State any conditions under which it will not work.

A body weighs, A g. in air, B g. in water, and C g. in a certain liquid. Find the specific gravity of the liquid.

6. Why is it possible to distinguish a note on the piano from the same note as given by a tuning fork?

What is meant by a longitudinal wave? Illustrate.

7. Where must an object be placed with a plano-convex lens to give a magnified real image? Where to produce a

virtual image? Will the latter be larger or smaller than the object?

8. Give diagram of the magnetic field of force about (*a*) two like poles; (*b*) two unlike poles.

What quantities determine the resistance of a conductor?

9. Describe a method of determining the direction of flow of an electric current.

Describe two methods for producing an electric current.

JUNE, 1907

1. Explain meaning of the following terms: *resultant force, moment of force, mass, power, parallelogram of forces.*

2. A rod, *AB*, 10 ft. long, of uniform cross section and weighing 10 lb., is pivoted 3 ft. from end, *A*. What force must be applied at the other end to keep the bar horizontal, when a weight of 20 lb. is hung at *A*?

3. What sort of motion exists in the following cases: (*a*) a body sliding down a frictionless inclined plane? (*b*) a body projected vertically upward in a vacuum? (*c*) an automobile in motion after the power of the engine is balanced by friction and air resistance? State reasons for your answers.

4. How much work is required to raise 500 gal. of water 100 ft. vertically? One gallon of water weighs 8.3 lb.

What horse power would be required to do this work in 3 min.?

Would it take more work to carry the water up an incline than to raise it vertically? Give reason for answer.

5. Explain a method for measuring the specific gravity of a solid and of a liquid.

How is it possible for a ship to carry a cargo of material that would sink if thrown overboard? What limits the weight of the cargo that can be carried?

6. Explain the construction and action of a mercurial thermometer.

If steam at 212° F. enters a radiator and after circulation leaves the same as water at 212° F., will the room be warmed? State reasons.

7. Why does a pool of water seem to the eye less deep than it really is?

It is desired to project a real, magnified image on a screen. Would it be possible to use (*a*) a plane mirror? (*b*) a concave mirror? (*c*) a convex mirror? Give reasons for your answers.

8. State what will happen under the following conditions, giving reasons in both cases: (*a*) if a bar magnet is floated on a piece of cork and is free to move; (*b*) if a lump of iron similarly floated is brought near the above bar magnet.

9. Two incandescent lamps have resistances 120 and 240 ohms respectively. What current will flow through each when they are joined (*a*) in series? (*b*) in parallel between two points maintained at a constant difference of potential of 120 volts?

SEPTEMBER, 1907

1. If two equal forces of magnitude 5 act for three minutes on two masses, 20 and 200, respectively, calculate: (*a*) acceleration of each; (*b*) space traversed by each in that time.

2. Under what circumstances will a suspended body be in equilibrium? What determines its stability?

Explain when a pivoted body will be in equilibrium under the action of a system of parallel forces.

3. Define the terms *potential energy* and *kinetic energy*, and give some examples of each.

How many pounds of water can be pumped per minute from a mine 500 ft. deep by an engine expending 20 h.p.?

4. A solid weighing 250 lb. has a specific gravity 5. Calculate its volume in cubic feet, assuming that 1 cu. ft. of water weighs 62.5 lb.

What force would be required to prevent this body from sinking if immersed in a liquid of specific gravity 1.5 ?

5. Explain the construction and uses of a mercurial barometer.

Why does a balloon filled with illuminating gas rise, and why does it not continue to ascend indefinitely ? If a balloon, while descending, enters a cooler layer of air, how will its speed of descent be affected ? Why ?

6. What is meant by the transference of heat by conduction, convection, and radiation ? Illustrate.

Can heat be transmitted through a vacuum ? Give your reasons.

Which would be the more effective in cooling hot water, 100 lb. of ice at 32° F. or 100 lb. of water at this temperature ? Why ?

7. Construct the images of an object in two plane mirrors at right angles. State the rule used in this construction.

What sort of lens should be used, and where should the object be placed to give a real, magnified image on a screen ?

8. How many voltaic cells, each of electromotive force 1.5 volts and internal resistance of $\frac{1}{2}$ ohm, would be required in series to send a current of $\frac{1}{6}$ ampere through a resistance of 51 ohms ?

9. Explain two methods for magnetizing a piece of steel.

What is a declination needle ?

What is a dipping needle ?

What is the effect of breaking a permanent magnet into small pieces ?

JUNE, 1908

1. Explain the following terms and give illustrations of each: motion, velocity, acceleration, moment of force, momentum, equilibrium.

2. A beam 20 feet long weighing 300 pounds rests horizontally on two supports, one at the end A, the other 4 feet from the opposite end. A man weighing 180 pounds stands on the beam 6 feet from A. Find the pressure on each support.

3. Explain the propagation of sound. What can you say of the experimental determination of the velocity of sound? What determines pitch? What are overtones?

4. A liter of air at 0° Centigrade and under a pressure of 76 cm. of mercury weighs 1.29 grams. What will be the weight of the same volume at a pressure of 10 atmospheres, and at 0° Centigrade?

5. Explain by diagram just how to locate images produced by a plane mirror. Explain fully what will happen to a ray of ordinary light when passed through a glass prism.

6. Explain exactly what you understand by the boiling point of a liquid. Explain why and how the boiling point changes with the height above sea level. How does evaporation differ from boiling?

7. Explain the difference in principle and in use between a gold leaf electroscope and a galvanometer. How does a voltaic cell differ in action from a charged Leyden jar?

8. One hundred cells, each having E. M. F. of 1.2 volts, are in series with a resistance of 50 ohms. The current is found to be 1.8 amperes. Find the resistance of the battery and of a single cell.

COLLEGE ENTRANCE EXAMINATION PAPERS

Massachusetts Institute of Technology

[NOTE. — The following heading appears on each paper.]

Time: two hours.

Physical laboratory notebooks are required in connection with this paper except for candidates coming from schools which are not able to meet the laboratory requirement, in which case a statement to that effect from the principal is required. Notebooks should be left at the Registrar's office, unless this has been done already.

The numerical work as well as the answer is required in the solution of problems.

JUNE, 1905

1. Define and illustrate meaning of terms: *inertia*, *momentum*, *velocity*, *density*, and *resultant force*. If two bodies, whose masses are in the ratio 6 : 8, are acted upon by two equal forces for the same length of time, what will be the ratio of their final velocities?

2. A weight of 100 lb. hangs from one end of the rod 8 ft. long which is pivoted 3 ft. from this end. Calculate the weight required at the other end to keep the rod horizontal. (Neglect weight of rod.)

3. How does uniform motion differ from uniformly accelerated motion, and under what circumstances is each produced? A well is 490 m. deep. How long will it take a stone to reach the bottom, if the acceleration of a falling body is 9.8 m.?

4. What is meant by a 6 h.p. engine? State kind of energy, kinetic or potential, present in the following cases: compressed spring, wheel of a moving car, water in reservoir, swinging pendulum.

5. If a bent U-tube contains mercury and water, show by diagram arrangement of the liquids for equilibrium. What is the specific gravity of a solid that weighs 10 g. in the air and 0 g. in water?

6. If a solid is heated from a temperature below its melting point to one above its boiling point, what will be the phenomena observed with a thermometer?

7. How does the intensity of a sound vary with the distance, and why? Define pitch of a sound. Construct the image of an object in a plane mirror. Is this image real or virtual?

8. State phenomena of electrification by friction. What are induced currents? Give an illustration of their production.

9. Describe three practical arrangements of 8 voltaic cells whose E.M.F. is 1.2 volts each, and internal resistance 8 ohms each. If the external resistance is 40 ohms, will the current be greater with cells in series or in parallel? Why?

SEPTEMBER, 1905

1. Define center of gravity and explain its relation to the stable and unstable equilibrium of suspended bodies. Define mass, density, weight, and illustrate each.

2. If a body falls 176.4 m. in 6 sec., what is its acceleration? How far will it fall during the first 4 sec.? What will be its velocity at the end of 6 sec.?

3. How does the time of vibration of a pendulum vary as the pendulum is carried up a mountain? Why? If the pendulum of a clock be lengthened, will the clock lose or gain time? Give reasons for answer.

4. Explain principle and construction of a mercurial barometer. What would be the effect of using water instead of mercury in the barometer?

5. The volume of a mass of air under a pressure of 75 lb. per square inch is 100 cu. in. What will its volume become if the pressure is increased to 100 lb. per square inch?

6. How does evaporation differ from boiling? What effect has pressure on the boiling point of a liquid? Illustrate.

7. Construct the image of an object placed between the principal focus and twice the focal distance of a double convex lens. State phenomena observed on the passage of a ray of light through a prism.

8. Explain process of charging a Leyden jar. Why does the addition of turns of wire about the needle of a galvanometer increase its sensitiveness for the same current?

9. If it takes 100 volts to generate a current of 21 amperes through a resistance of 5 ohms, what electro-motive force will be necessary to generate $\frac{1}{4}$ the current through a resistance of 10 ohms?

JUNE, 1906

1. If a force of 60 units, acting on a mass of 12 units, generates 180 units of momentum in 3 sec., what force would produce the same momentum in $\frac{1}{100}$ sec.?

What is meant by the statement, "The velocity of a freely falling body is 160 ft. per second at the end of 5 sec. from rest"?

2. The leaning tower of Pisa is inclined 14 ft. from the vertical. Why does it not fall?

Explain necessity of "banking" the curves of a bicycle track.

3. Forces 6, 5, 8 acting on a pivoted body at perpendicular distances 5, 3, 4 respectively from the pivot, tend to produce rotation in same direction. How must a force of 11 be applied to preserve equilibrium?

Will the height to which a body rises above its starting point, when projected vertically upward with a velocity V, be the same at the base as at the top of a lofty mountain? Explain.

4. How much energy does a mass weighing 2 T. acquire in falling through 100 ft.?

If the specific gravity of a solid whose volume is 25 cc. is 0.8, calculate the volume and weight of water that it will displace when floating.

5. A tube 10 ft. long and closed at one end is filled with water. If this tube is placed in a vertical position with the open end under water, why does not the water run out of the tube?

Do sounds of different pitch travel in air with the same velocity? Give reasons for answer.

6. Why does a lake freeze from the surface downward? Would a mass of molten lead, on cooling, also solidify from surface downward? State clearly.

7. What is the difference between the phenomena of reflection from white blotting paper and from a piece of window glass?

Why is the beam of a powerful search light visible at night?

Where would you place an object with a spherical concave mirror to obtain (*a*) a real magnified image? (*b*) a virtual image?

8. How will a permanent magnet place itself if suspended? How will it place itself (*a*) if another suspended magnet is

brought near it? (*b*) a suspended piece of iron? (*c*) a suspended piece of zinc? Explain two methods of magnetizing a piece of steel.

9. Explain cause of divergence of leaves of a gold-leaf electroscope on the approach of a charged body.

What effect have the size of the plates in a voltaic cell and their distance apart on (*a*) the resistance of the cell? (*b*) the potential of the cell?

SEPTEMBER, 1906

1. Resolve a force of 90 lb. into two components at right angles to each other, one being three times the other. Explain an arrangement of pulleys for raising 500 lb. by a force of less than 500 lb.

2. State Newton's three laws of motion. Illustrate each.

3. What is a resultant force? Illustrate.

A body of mass, M, is given an original velocity, V. If a constant force, F, opposes the motion, write out the formula for the velocity of the body at end of time, t.

4. Under what circumstances does a force acting upon a body do work? What measures the amount of work? Will it require 6 h.p. to do 198,000 ft.-lb. of work? Explain.

5. Explain principle of the siphon. State any conditions under which it will not work.

A body weighs, A g. in air, B g. in water, and C g. in a certain liquid. Find the specific gravity of the liquid.

6. Why is it possible to distinguish a note on the piano from the same note as given by a tuning fork?

What is meant by a longitudinal wave? Illustrate.

7. Where must an object be placed with a plano-convex lens to give a magnified real image? Where to produce a

virtual image? Will the latter be larger or smaller than the object?

8. Give diagram of the magnetic field of force about (*a*) two like poles; (*b*) two unlike poles.

What quantities determine the resistance of a conductor?

9. Describe a method of determining the direction of flow of an electric current.

Describe two methods for producing an electric current.

JUNE, 1907

1. Explain meaning of the following terms: *resultant force, moment of force, mass, power, parallelogram of forces.*

2. A rod, *AB*, 10 ft. long, of uniform cross section and weighing 10 lb., is pivoted 3 ft. from end, *A*. What force must be applied at the other end to keep the bar horizontal, when a weight of 20 lb. is hung at *A*?

3. What sort of motion exists in the following cases: (*a*) a body sliding down a frictionless inclined plane? (*b*) a body projected vertically upward in a vacuum? (*c*) an automobile in motion after the power of the engine is balanced by friction and air resistance? State reasons for your answers.

4. How much work is required to raise 500 gal. of water 100 ft. vertically? One gallon of water weighs 8.3 lb.

What horse power would be required to do this work in 3 min.?

Would it take more work to carry the water up an incline than to raise it vertically? Give reason for answer.

5. Explain a method for measuring the specific gravity of a solid and of a liquid.

How is it possible for a ship to carry a cargo of material that would sink if thrown overboard? What limits the weight of the cargo that can be carried?

6. Explain the construction and action of a mercurial thermometer.

If steam at 212° F. enters a radiator and after circulation leaves the same as water at 212° F., will the room be warmed? State reasons.

7. Why does a pool of water seem to the eye less deep than it really is?

It is desired to project a real, magnified image on a screen. Would it be possible to use (*a*) a plane mirror? (*b*) a concave mirror? (*c*) a convex mirror? Give reasons for your answers.

8. State what will happen under the following conditions, giving reasons in both cases: (*a*) if a bar magnet is floated on a piece of cork and is free to move; (*b*) if a lump of iron similarly floated is brought near the above bar magnet.

9. Two incandescent lamps have resistances 120 and 240 ohms respectively. What current will flow through each when they are joined (*a*) in series? (*b*) in parallel between two points maintained at a constant difference of potential of 120 volts?

SEPTEMBER, 1907

1. If two equal forces of magnitude 5 act for three minutes on two masses, 20 and 200, respectively, calculate: (*a*) acceleration of each; (*b*) space traversed by each in that time.

2. Under what circumstances will a suspended body be in equilibrium? What determines its stability?

Explain when a pivoted body will be in equilibrium under the action of a system of parallel forces.

3. Define the terms *potential energy* and *kinetic energy*, and give some examples of each.

How many pounds of water can be pumped per minute from a mine 500 ft. deep by an engine expending 20 h.p.?

4. A solid weighing 250 lb. has a specific gravity 5. Calculate its volume in cubic feet, assuming that 1 cu. ft. of water weighs 62.5 lb.

What force would be required to prevent this body from sinking if immersed in a liquid of specific gravity 1.5 ?

5. Explain the construction and uses of a mercurial barometer.

Why does a balloon filled with illuminating gas rise, and why does it not continue to ascend indefinitely ? If a balloon, while descending, enters a cooler layer of air, how will its speed of descent be affected ? Why ?

6. What is meant by the transference of heat by conduction, convection, and radiation ? Illustrate.

Can heat be transmitted through a vacuum ? Give your reasons.

Which would be the more effective in cooling hot water, 100 lb. of ice at 32° F. or 100 lb. of water at this temperature ? Why ?

7. Construct the images of an object in two plane mirrors at right angles. State the rule used in this construction.

What sort of lens should be used, and where should the object be placed to give a real, magnified image on a screen ?

8. How many voltaic cells, each of electromotive force 1.5 volts and internal resistance of $\frac{1}{2}$ ohm, would be required in series to send a current of $\frac{1}{6}$ ampere through a resistance of 51 ohms ?

9. Explain two methods for magnetizing a piece of steel.

What is a declination needle ?

What is a dipping needle ?

What is the effect of breaking a permanent magnet into small pieces ?

JUNE, 1908

1. Explain the following terms and give illustrations of each: motion, velocity, acceleration, moment of force, momentum, equilibrium.

2. A beam 20 feet long weighing 300 pounds rests horizontally on two supports, one at the end A, the other 4 feet from the opposite end. A man weighing 180 pounds stands on the beam 6 feet from A. Find the pressure on each support.

3. Explain the propagation of sound. What can you say of the experimental determination of the velocity of sound? What determines pitch? What are overtones?

4. A liter of air at 0° Centigrade and under a pressure of 76 cm. of mercury weighs 1.29 grams. What will be the weight of the same volume at a pressure of 10 atmospheres, and at 0° Centigrade?

5. Explain by diagram just how to locate images produced by a plane mirror. Explain fully what will happen to a ray of ordinary light when passed through a glass prism.

6. Explain exactly what you understand by the boiling point of a liquid. Explain why and how the boiling point changes with the height above sea level. How does evaporation differ from boiling?

7. Explain the difference in principle and in use between a gold leaf electroscope and a galvanometer. How does a voltaic cell differ in action from a charged Leyden jar?

8. One hundred cells, each having E. M. F. of 1.2 volts, are in series with a resistance of 50 ohms. The current is found to be 1.8 amperes. Find the resistance of the battery and of a single cell.

Harvard University

[NOTE.—The following heading appears on each paper.]

Time: one hour.

All notebooks must be handed in at the laboratory examination, and must be claimed when it is over.

Omit four of the following questions.

JUNE, 1905

1. A reservoir filled with water is 10 m. deep and has a base 1 m. square. What is the total pressure exerted on the bottom of the reservoir, the barometric pressure on the top of the water being 76 cm. and the density of mercury 13.6?

2. Represent by a diagram a system of pulleys by means of which, if there were no friction, a weight of 1 lb. would just balance a weight of 4 lb.

3. A bullet weighing 2 g. is shot vertically upward into a suspended block weighing 998 g. The velocity of the bullet just before it strikes the block is 50,000 cm. per second.

(*a*) How great is the velocity imparted to the block?

(*b*) How high will the block rise?

4. (*a*) About how great is the velocity of sound in the atmosphere?

(*b*) What effect, if any, would increase of temperature have on this velocity?

(*c*) What effect, if any, would increase of atmospheric pressure have on this velocity?

5. If 200 g. of metal of specific heat 0.1 is brought to the temperature of steam at a pressure of 76 cm. of mercury,

and is then dropped into a vessel containing 100 g. of water and 10 g. of ice well mixed, what will be the resulting temperature of the whole? (Neglect the heat absorbed by the vessel.)

6. If a door between a warm and a cold room stands open a few inches and a lighted candle be moved upward and downward in the opening, the flame will be blown from the warm room toward the cold room at the top of the door, and from the cold room to the warm room at the bottom. Why?

7. (*a*) Define the following terms: *principal focus*, *virtual image*.

(*b*) Illustrate each of these terms by means of diagrams, showing the action of a concave mirror.

8. Explain, by means of a diagram, the action of an ordinary magnifying glass.

9. Describe the action of a Leyden jar, and explain why it is sometimes called an electric condenser.

10. Two cells, each having a resistance of 2 ohms and an electromotive force of 1.5 volts, are connected in series to the binding posts of a galvanometer having a resistance of 6 ohms. These binding posts are connected also by a wire having a resistance of 3 ohms.

(*a*) How great is the current through the cells?

(*b*) How great is the current through the 6 ohm coils of the galvanometer?

SEPTEMBER, 1905

1. A bar of metal, 20 cm. long and 1 sq. cm. in cross section, floats upright in mercury with 15 cm. of its length beneath the mercury surface. The density of mercury is 13.6. What is the weight of 1 cc. of the metal?

2. A machinist exerts upon a file a force of 10 lb. downward and 15 lb. forward. How much work does he do in 40 horizontal strokes, each 6 in. long? In what units is the result expressed? Does the vertical pressure enter into the calculation of the work? Why?

3. A "Mariotte's bottle" has the bottom of the vertical tube some distance below the highest of the side orifices. At the beginning of the experiment the side orifices are closed and the bottle and tube are full of water. Describe and explain, with the aid of a diagram, what will happen when the highest side orifice is opened.

4. Define the terms *fundamental tone*, *harmonics*, and *node*, and illustrate them by means of a diagram of a vibrating string.

5. If a certain weight of air has a volume of 1000 cu. m. when the temperature is 0° C., and the barometric pressure is 76, how much space will it occupy when the temperature is 30° C. and the barometric pressure 74 cm.?

6. (*a*) Define *coefficient of linear expansion.*

(*b*) If the diameter of an iron disk is 12 cm. at 0° C., how great will it be at 50° C., if the coefficient of linear expansion is 0.000012?

7. Show, with a diagram, how a projecting lantern can be used to throw upon a screen the spectrum of the light from an arc lamp.

8. A picture and a screen are 25 ft. apart. A lens is to be used to throw upon the screen an image of the picture, each dimension magnified fourfold.

(*a*) How far from the picture must the lens be placed?

(*b*) How great must be the focal length of the lens?

9. A so-called "water battery," each cell consisting of a strip of zinc and copper in pure water, has about the same

electromotive force, cell for cell, as a battery of Daniell cells, as shown by means of a static electroscope. But 50 cells of the water battery, connected in series, will not give as much current through a low external resistance (of, for example, 5 ohms) as a single Daniell cell. Why is this?

10. Make a sketch of a very simple telegraph line, showing instruments at both ends, and explain briefly the mode of working.

JUNE, 1906

1. A body having a volume of 150 cc. and a density of 1.1 g. per cubic centimeter is placed in water with 50 cc. of wood, of density 0.6, beneath it. How many cubic centimeters of the body will remain above the surface of the water?

2. (*a*) Describe, with a diagram, the action of a siphon.

(*b*) Tell what difficulty would be encountered in the long-continued working of a tall siphon carrying ordinary water, which contains considerable air.

3. A uniform beam, 20 ft. long, and weighing 100 lb., rests in a horizontal position on a fulcrum 4 ft. from one end, and just at this end presses against the under side of a second beam:

(*a*) How great is the upward pressure exerted on the second beam?

(*b*) How great is the downward pressure exerted on the fulcrum?

4. (*a*) What makes the difference between a musical note and a mere noise?

(*b*) What is the use of the wooden part of a violin in addition to its service as a frame to hold the strings?

5. (*a*) Explain the circulation of water in a hot-water system of heating, in which there is no pump or engine to drive the liquid.

(*b*) Tell why a long steam pipe or hot-water pipe should not be rigidly fastened to the wall of a building.

6. Water would have to fall about 1400 ft. in order to be heated 1° C. by the work done upon it by the earth's attraction during this fall. If the specific heat of mercury is 0.032, how many foot-pounds of work would be required to increase the temperature of 5 lb. of mercury 1° C.?

7. (*a*) A horizontal beam of sunlight is refracted by a prism in such a way that the resulting spectrum is thrown upward against a vertical wall. Name the main divisions of this spectrum in their natural order, beginning with the lowest.

(*b*) In what general way does the spectrum of a metal burning in the electric arc differ from the spectrum of sunlight?

8. Show, with the aid of a diagram, how you would measure the light-giving power of an incandescent electric lamp in terms of the power of a candle.

9. (*a*) A gutta-percha rod, after being rubbed with catskin to give it a negative charge of electricity, is held a little distance above the top of a gold-leaf electroscope. Show, with a diagram, the behavior and the state of charge of the electroscope.

(*b*) While the rod is held as before, the upper part of the electroscope is connected for a moment with the earth, then disconnected. Show, with a diagram, the resulting behavior and state of charge of the electroscope.

(*c*) The rod is now removed. Show, with a diagram, the final behavior and state of charge of the electroscope.

10. (*a*) If an arc lamp requires a current of 10 amperes and a difference of potential at its terminals of 50 volts, how great is its resistance?

(*b*) How many watts does it require?

(*c*) What part of a horse power does it use?

SEPTEMBER, 1906

1. A body having a volume of 150 cc. and a density of 1.2 g. per cubic centimeter is placed in water with 50 cc. of wood, of density 0.6, attached to it. The whole combination being submerged in the water, how great is the force required to keep it from sinking farther?

2. Describe capillary action, and mention any familiar domestic use of such action.

3. A rectangular board, 2 ft. long and 1 ft. wide, is placed with its longer dimension extending east and west, while its shorter dimension extends north and south. A force of 10 lb. acting due east is applied at the northeast corner, and an equal force acts due west at the southwest corner. These two forces are to be balanced by a second pair acting at right angles with the first pair, one of the second pair being applied at the northwest corner, the other at the southeast corner. What is the magnitude of each of the second pair of forces, and what is the direction of the force applied at the northwest corner?

4. (*a*) Show, with diagrams, the position of the nodes in an organ pipe closed at one end, first, when the pipe is giving its lowest note, second, when the pipe is giving the next higher note of which it is capable.

(*b*) If the number of vibrations per second of the lowest note is n, what is the corresponding number for the next higher note in this case?

5. Explain, as fully as you can, why some kinds of food which can be cooked in water boiling in open vessels at the sea level cannot be well cooked in the same way on high mountains, but can be properly cooked there in water boiling in tightly closed vessels.

6. Describe carefully any laboratory exercise in which you have measured heat, as distinguished from temperature.

7. Define, with the aid of a diagram, the term index of refraction, and show what is meant by the statement that this index is always the same for a given material — for example, a particular kind of glass.

8. If the focal length of the object glass of a simple telescope is 30 cm. and the focal length of the single-lens eyepiece 5 cm., the two lenses being 34 cm. apart, how far from the eyepiece will be the virtual image of a distant object toward which the telescope is directed?

9. Describe, with a diagram, any system of "wireless telegraphy."

10. Describe the construction, charging, and discharging of storage cells.

JUNE, 1907

1. A hammer whose head weighs 500 g. and whose handle weighs 400 g. is submerged in water. The specific gravity of the steel head is 8. The specific gravity of the handle is .6. What is the force required to keep it from sinking or floating?

2. Why does frost occur on clear nights particularly?

3. Show, by means of a diagram, an arrangement of a lever whereby a man exerting a force of 50 lb. upward could just lift a weight of 20 lb. What other force acts on the lever? Show its direction and magnitude.

4. Explain the phenomenon of resonance and the action of a Helmholtz resonator.

5. If 1000 g. of water at a temperature of 80° C. and 400 g. of mercury at 30° (specific heat 0.032) are poured into a vessel weighing 500 g. initially at a temperature of 20° C. and

having a specific heat 0.1, what will be the temperature of the two, assuming no loss in the process?

6. What is the ratio between the cubical and the linear coefficients of expansion? Explain.

7. Define, with the aid of a diagram, the term index of refraction, and show what is meant by the statement that this index is always the same for a given color of light and a given material — for example, a particular kind of glass.

8. If the resistance of a wire 10 m. long and 1 mm. in diameter is .2 ohm, how great is the resistance of a wire of the same material 5 m. long and .4 mm. in diameter?

9. By a diagram show the connections of a Wheatstone's bridge. If the bridge is being used to measure the resistance of a coil x by balancing it against a resistance of 10 ohms, and if balance is secured when the wire is divided by the bridge into two parts, 72 cm. and 28 cm. right and left respectively, as shown on your diagram, what is the resistance of x?

10. Explain the method of artificial refrigeration or of making ice artificially.

SEPTEMBER, 1907

1. A man who just floats in fresh water floats with $\frac{1}{10}$ of his body above the surface in Salt Lake. What is the specific gravity of the water of Salt Lake?

2. Explain, giving the physical reasons, why a sea breeze is generally cooler than a land breeze in the summer.

3. Show by a diagram a system of pulleys by means of which a man, weighing 150 lb., pulling down on one end of the rope, could just lift a stone weighing slightly under 750 lb.

4. How may the velocity of sound be determined? What would be the effect, if any, of an increase in temperature on the velocity of sound?

5. If the ends of the rails of a track just touch at 30° C., what is the average distance between the ends of the rails at a temperature of — 10° C., the length of the rail being 10 m. and the coefficient of expansion 0.000012 ? Assume the rails free to contract.

6. Water falling to the ground from a height of 424 m. would generate sufficient heat to raise its own temperature 1° C. How much ice (latent heat 80) could be melted by the heat generated by the falling of a mass of lead weighing 80 kg. from a height of 1000 m.?

7. Explain (do not merely describe) one form of photometer.

8. A street car, running on a system in which the difference of potential between trolley wire and track is 500 volts, requires 15 amperes to run it on a certain grade. What is the number of watts used ? What is the horse power used?

9. Draw a diagram showing a simple telephone system using a battery. It will be sufficient to show a system which will transmit in one direction only, but the connections and the nature of all the parts must be clearly indicated.

10. Why does the apparent force of gravity vary at different points of the earth's surface ?

JUNE, 1908

1. A block of wood of volume 100 cc. and specific gravity .75 floats in a certain liquid with $\frac{2}{3}$ of the volume of the block beneath the surface of the liquid; what is the specific gravity of the liquid ?

2. On a certain day a mercury barometer reads 76 cm. at the base of a high building and 75 cm. at the top of the building. What is the height of the building? Take the density of mercury to be 13.6 g. per cubic centimeter; as-

sume the air between the bottom and top of the building to have a uniform density of .0012 g. per cubic centimeter.

3. (*a*) Define *dyne* and *erg*.

(*b*) How many dynes of force acting upon a mass of 10 g. for 2 sec. will give it a velocity of 100 cm. per second?

(*c*) How much work is done in the process?

4. A body starting from rest falls freely under the action of the earth's attraction.

(*a*) What will be its velocity at the end of 3 sec.?

(*b*) How far will it fall during the third second?

5. Make a clear sketch of two simple machines of different classes by which a force of 8 lb. can support a weight of 32 lb. Indicate on the sketch the essential numerical dimensions of the parts of each machine.

6. Describe, with the aid of a diagram, one form of clock pendulum that compensates for changes of temperature.

7. How does the presence of water on the earth tend to prevent extremes of heat and cold?

8. Describe a compound microscope. Make a diagram, and show the principal focus of each lens and the path of the light rays.

9. If a printed page at a distance of 1 m. from a 16-candle-power incandescent lamp is illuminated to an intensity for comfortable reading, at what distance from an arc lamp of 2000 candle power will the printed page be illuminated to the same intensity?

10. If an incandescent lamp requires a current of .5 ampere and a difference of potential of 110 volts at its terminals,

(*a*) How great is its resistance?

(*b*) How many such lamps may be supplied with power by a 2-kilowatt electric generator?

Sheffield Scientific School, Yale University

Time: fifty-five minutes.

JUNE, 1905

1. A body of 30 grams mass is constrained to move in a horizontal circle of 60-cm. radius, by a central force of 3200 dynes. One second after passing the north point of the circle, the constraint suddenly ceases. Find the amount and direction of the immediately subsequent velocity.

2. Tell something of the propagation of sound, and how you would set about measuring the velocity.

3. Describe the phenomena of melting and of boiling. Tell how these would be modified by pressure.

4. State exactly what magnetic properties are exhibited by a circular coil of wire conveying a current. Illustrate by drawing lines of force.

5. Describe the phenomenon of current induction. Who discovered it?

6. Mention some of the reasons for believing that light is a wave phenomenon.

JUNE, 1906

1. A constant force acting on a mass of 10 g. for 5 sec. produces a velocity of 100 cm. per second. What velocity would this force produce in 10 sec. when acting on a mass of 50 g.?

2. If a horse walk at the rate of 2.5 mi. an hour, at the same time raising a weight of 150 lb. through a vertical distance equal to the distance traveled, how much work does he do per minute?

3. Describe the phenomenon of beats when two notes are sounded together. How is it explained?

4. Explain and illustrate by a diagram the characteristic changes in his image which may be observed by a person as he approaches a spherical concave mirror.

5. How is a quantity of heat measured? What is meant by specific heat of a substance?

6. What is a Leyden jar? Explain its use.

7. What magnetic effect is produced by a current flowing in a straight conductor?

SEPTEMBER, 1906

1. If a stone is thrown vertically to the height of 60 ft., how long will it take to return to the level from which it started?

2. What would be the length of a seconds pendulum where the acceleration of weight is 162 cm. per second in a second?

3. Calculate the wave length in air of the standard pitch $a = 435$ vibrations per second.

4. What does a prism do to light? How does the analysis of light by a prism give knowledge of the source of light?

5. What is meant by the equivalence of heat and work? State exactly what the relation is.

6. Explain the construction and use of the secondary or storage cell.

7. How may a current be *induced* in a conductor? Show how to predict its direction.

JUNE, 1907

1. Find the length of a lead rod having a mass of 1.52 kg., a diameter of 1.25 cm., and a density of 11.3 g. per cubic centimeter.

2. A 15-g. bullet moving with a velocity of 600 m. per second penetrates 32 cm. of wood. What is the average resistance (force) to penetration?

3. What is a barometer? Describe one or more of the familiar forms and their uses.

4. What is Boyle's Law? What simple method may be employed for investigation of this law?

5. Describe the magnetic field due to a helix conveying a current. Show how to find the north pole of the solenoid.

6. What is meant by the fundamental, and what by the overtones, of a musical string? What influence do the overtones have upon the sound?

7. Describe and explain the colors of thin plates, or of Newton's rings.

SEPTEMBER, 1907

1. A train moving 60 mi. an hour is brought to rest by a uniformly applied brake. Calculate the retardation (negative acceleration).

2. A boat crossing a river which flows 5 mi. an hour heads 30° upstream and reaches a point directly opposite the starting place. At what speed did the boat run?

3. In what particulars is the behavior of a vapor different from that of a gas?

4. Describe the action of the induction or spark coil as completely as possible.

5. Describe several different kinds of waves and the phenomena to which they may give rise.

6. If an object at the bottom of a vessel be viewed directly from above, explain what change will be observed on filling the vessel with water.

JUNE, 1908

1. If a body starting from rest moves a distance of 1000 meters in 30 seconds under the action of a force of 50 dynes, what is the mass of the body?

2. Explain the principle of the ordinary thermometer and describe how the graduation is effected.

3. State what is meant by wave length, amplitude, frequency, and wave velocity. Write a relation which exists between some of these quantities.

4. What is the distinction between the primary, and the secondary or storage cell? Describe fully some primary cell with which you are familiar and point out any advantages or disadvantages it may possess.

5. What is an induced current? State what you can about the amount and direction of the induced current.

6. Describe different kinds of spectra and tell something of their origin.

APPENDIX

TABLES AND PHYSICAL CONSTANTS

METRIC SYSTEM

Linear Measure

10 millimeters (mm.)	=	1 centimeter (cm.)
10 cm.	=	1 decimeter (dm.)
10 dm.	=	1 meter (m.)
10 m.	=	1 Dekameter (Dm.)
10 Dm.	=	1 Hektometer (Hm.)
10 Hm.	=	1 Kilometer (Km.)

Square Measure

100 square millimeters ($mm.^2$) = 1 square centimeter ($cm.^2$)

Etc.

Cubic Measure

1000 cubic millimeters ($mm.^3$) = 1 cubic centimeter (cc.)

Etc.

Liquid and Dry Measure

10 milliliters (ml.) = 1 centiliter (cl.)

Etc.

(The liter has the same volume as the $dm.^3$)

Weight

10 milligrams (mg.) = 1 centigram (cg.)

Etc.

(The gram is the weight of 1 cc. of distilled water at 4° C.)

English and Metric Equivalents

1 inch	= 2.54 cm.	1 meter	= 39.37 in.
1 mile	= 1.61 Km.	1 liter	= 1.06 qt. (liquid)
1 ounce	= 28.35 g.		
1 pound	= 0.4536 kg.	1 kilogram	= 2.20 lb.

SPECIFIC GRAVITIES

SOLIDS

Aluminum	2.6	Iron, wrought	7.8
Brass	8.4	Lead	11.4
Copper	8.9	Marble	2.7
Granite	2.6	Pine, white, dry	0.42
Gold	19.3	Silver	10.5
Ice	0.918	Tin	7.3
Iron, cast	7.2	Zinc	7.1

LIQUIDS AT 0° C.

Alcohol	0.8	Mercury	13.6
Copper sulphate solution	1.2	Sea water	1.03
Ether	0.73	Sulphuric acid, conc.	1.84
Kerosene	0.79		

APPROXIMATE WEIGHTS

1 cubic foot of water weighs approximately 62.5 lb.
1 cubic foot of air at 76 cm. and 0° C. weighs approximately 0.081 lb.
1 liter of air at 76 cm. and 0° C. weighs approximately 1.29 g.

GEOMETRICAL FORMULÆ

Right triangle: square of hypothenuse = sum of squares of legs.

Circumference of circle $= 2\pi R$

Area of circle $= \pi R^2$

Surface of sphere $= 4\pi R^2$

Volume of sphere $= \frac{\pi D^3}{6}$

VELOCITY OF SOUND

At 0° C., in air = 1090 ft. per sec. or 332 m. per sec.
Increase per degree C. rise = 2 ft. per sec. or 0.6 m. per sec.

THERMODYNAMIC EQUIVALENT

Energy required to heat 1 lb. water 1° C., = 1400 ft.-lb.
Energy required to heat 1 lb. water 1° F., = 778 ft.-lb.
1 calorie = 3.09 ft.-lb. = 0.427 kg.-m.

HEAT CONSTANTS

Substance	*Cubical Coef. of Expansion 0°–100° C.	*Specific Heat (Approx.)	Melting Point, Centigrade (Approx.)	Boiling Point, Centigrade (Approx.)	Heat of Fusion, Gm.Deg.C.	Heat of Vaporization, Gm.Deg.C.
Alcohol . .	0.001040	0.61	— 130	78	—	209
Aluminum .	0.000069	0.22	625	—	—	—
Brass . . .	0.000057	0.093	900	—	—	—
Chloroform .	0.001399	0.23	—	—	—	58
Copper . .	0.000051	0.094	1100	—	—	—
Ether . . .	0.002150	0.53	—	35	—	90
Glass . . .	0.000028	0.19	—	—	—	—
Ice . . .	−20° to 0°C. 0.000112	0.50	0	—	80	—
Iron, cast. .	0.000032	0.11	1100	—	23	—
Iron, wrought	0.000034	0.11	1600	—	—	—
Lead . . .	0.000088	0.031	326	1500	5.6	—
Mercury . .	0.000182	0.033	— 39	357	2.8	—
Platinum . .	0.000027	0.032	1900	—	—	—
Silver . . .	0.000057	0.056	950	—	21	—
Steam . . .	—	0.4	—	—	—	536
Steel . . .	0.000038	0.120	1360	—	—	—
Water . . .	—	1.000	0	100	80	536
Zinc . . .	0.000088	0.094	415	960	28	—

RELATIVE RESISTANCES

Copper (often taken as the standard)	1
German silver (varies with different alloys)	18
Iron (telegraph wire)	7.5

ELECTRO-CHEMICAL EQUIVALENTS

Copper	0.000329
Nickel	0.000305
Silver	0.001118
Hydrogen	0.000010

* The values given in this column are correct only for temperatures between 0° and 100° C., but they are to be used throughout this book as correct for all temperatures given.

WIRE TABLES

AMERICAN OR BROWN & SHARPE (B. & S.) GAUGE

Gauge No.	Diameter in Mils.	Area in Circular Mils.	Diameter in mm.	Safe Carrying Capacity for Copper, Amperes
0000	460.000	211,600.00	11.68	312
000	409.640	167,805.00	10.40	262
00	364.800	133,079.40	9.27	220
0	324.865	105,534.50	8.25	185
1	289.300	83,694.20	7.35	156
2	257.630	66,373.00	6.54	131
3	229.420	52,634.00	5.83	110
4	204.310	41,742.00	5.19	92
5	181.940	33,102.00	4.62	77
6	162.020	26,250.50	4.12	65
7	144.280	20,816.00	3.67	56
8	128.490	16,509.00	3.26	46
9	114.430	13,094.00	2.91	39
10	101.890	10,381.00	2.59	32
11	90.742	8,234.00	2.31	27
12	80.808	6,529.90	2.05	23
13	71.961	5,178.40	1.83	19
14	64.084	4,106.80	1.63	16
15	57.068	3,256.70	1.45	10
16	50.820	2,582.90	1.29	8
17	45.257	2,048.20	1.15	6
18	40.303	1,624.30	1.02	5
19	35.390	1,288.10	.90	
20	31.961	1,021.50	.81	
21	28.462	810.10	.72	
22	25.347	642.70	.64	
23	22.571	509.45	.57	
24	20.100	404.01	.51	
25	17.900	320.40	.46	
26	15.940	254.01	.41	
27	14.195	201.50	.36	
28	12.641	159.79	.32	
29	11.257	126.72	.29	
30	10.025	100.50	.26	
31	8.928	79.71	.23	
32	7.950	63.20	.20	
33	7.080	50.13	.18	
34	6.304	39.74	.16	
35	5.614	31.52	.14	
36	5.000	25.00	.13	
37	4.453	19.83	.11	
38	3.965	15.72	.10	
39	3.531	12.47	.09	
40	3.144	9.89	.08	

FOUR-PLACE LOGARITHM TABLES

N	0	1	2	3	4	5	6	7	8	9	P. P. 1. 2. 3. 4. 5
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	4. 8.12.17.21
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4. 8.11.15.19
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3. 7.10.14.17
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3. 6.10.13.16
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3. 6. 9.12.15
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3. 6. 8.11 14
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	3. 5. 8 11.13
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	2. 5. 7.10.12
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2. 5. 7. 9.12
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2. 4. 7. 9.11
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2. 4. 6. 8.11
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2. 4. 6. 8.10
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2. 4. 6. 8.10
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2. 4. 5. 7. 9
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2. 4. 5. 7. 9
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2. 3. 5. 7. 9
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2. 3. 5. 7. 8
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2. 3. 5. 6. 8
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2. 3. 5. 6. 8
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1. 3. 4. 6. 7
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1. 3. 4. 6. 7
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1. 3. 4. 6. 7
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1. 3. 4. 5. 7
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1. 3. 4. 5. 6
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1. 3. 4. 5. 6
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1. 2. 4. 5. 6
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1. 2. 4. 5. 6
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1. 2. 3. 5. 6
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1. 2. 3. 5. 6
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1. 2. 3. 4. 6
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1. 2. 3. 4. 5
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1. 2. 3. 4. 5
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1. 2. 3. 4. 5
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1. 2. 3. 4. 5
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1. 2. 3. 4. 5
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1. 2. 3. 4. 5
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1. 2. 3. 4. 5
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1. 2. 3. 4. 5
48	0812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1. 2. 3. 4. 4
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1. 2. 3. 4. 4
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1. 2. 3. 3. 4
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1. 2. 3. 3. 4
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1. 2. 2. 3. 4
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1. 2. 2. 3. 4
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1. 2. 2. 3. 4
N	0	1	2	3	4	5	6	7	8	9	

				3	4	5	6	7	8	9	P. P. 1. 2. 3. 4. 5
				7427	7435	7443	7451	7459	7466	7474	1. 2. 2. 3. 4
				7505	7513	7520	7528	7536	7543	7551	1. 2. 2. 3. 4
				7582	7589	7597	7604	7612	7619	7627	1. 2. 2. 3. 4
				7657	7664	7672	7679	7686	7694	7701	1. 1. 2. 3. 4
				7731	7738	7745	7752	7760	7767	7774	1. 1. 2. 3. 4
				7803	7810	7818	7825	7832	7839	7846	1. 1. 2. 3. 4
				7875	7882	7889	7896	7903	7910	7917	1. 1. 2. 3. 4
				7945	7952	7959	7966	7973	7980	7987	1. 1. 2. 3. 3
				8014	8021	8028	8035	8041	8048	8055	1. 1. 2. 3. 3
				8082	8089	8096	8102	8109	8116	8122	1. 1. 2. 3. 3
				8149	8156	8162	8169	8176	8182	8189	1. 1. 2. 3. 3
				8215	8222	8228	8235	8241	8248	8254	1. 1. 2. 3. 3
				8280	8287	8293	8299	8306	8312	8319	1. 1. 2. 3. 3
				8344	8351	8357	8363	8370	8376	8382	1. 1. 2. 3. 3
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1. 1. 2. 3. 3
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1. 1. 2. 2. 3
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1. 1. 2. 2. 3
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1. 1. 2. 2. 3
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1. 1. 2. 2. 3
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1. 1. 2. 2. 3
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1. 1. 2. 2. 3
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1. 1. 2. 2. 3
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1. 1. 2. 2. 3
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1. 1. 2. 2. 3
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1. 1. 2. 2. 3
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1. 1. 2. 2. 3
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1. 1. 2. 2. 3
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1. 1. 2. 2. 3
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1. 1. 2. 2. 3
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1. 1. 2. 2. 3
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1. 1. 2. 2. 3
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1. 1. 2. 2. 3
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0. 1. 1. 2. 2
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0. 1. 1. 2. 2
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0. 1. 1. 2. 2
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0. 1. 1. 2. 2
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0. 1. 1. 2. 2
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0. 1. 1. 2. 2
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0. 1. 1. 2. 2
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0. 1. 1. 2. 2
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0. 1. 1. 2. 2
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0. 1. 1. 2. 2
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0. 1. 1. 2. 2
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0. 1. 1. 2. 2
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0. 1. 1. 2. 2
N	0	1	2	3	4	5	6	7	8	9	